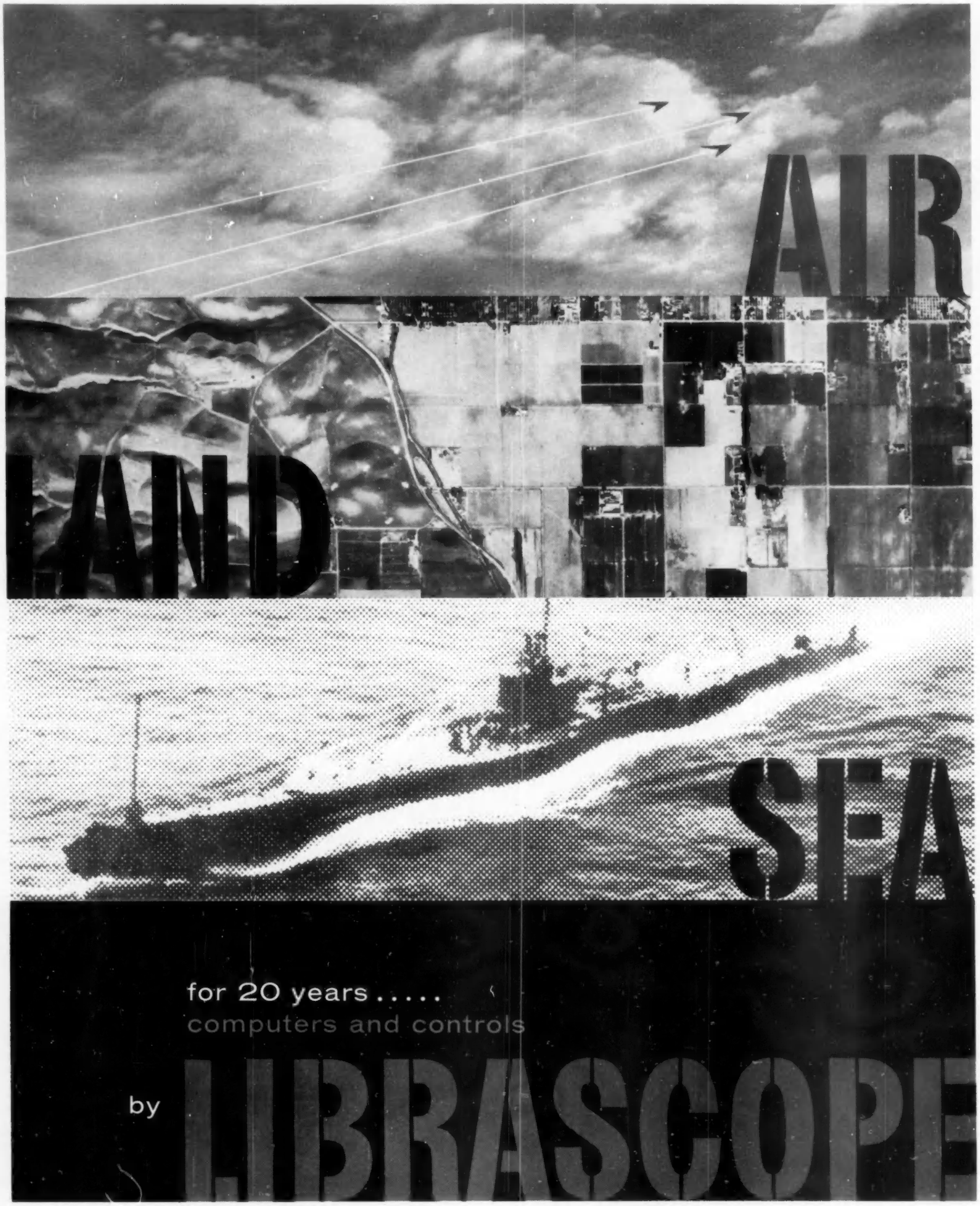
Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

JUNE 1957

New Centers for Control



EXPERIENCE AND VERSATILITY have earned for Librascope a position of leadership in the design, development and manufacture of computers and controls for military and industrial applications. Through extensive experience in the combination of electronic, magnetic, mechanical and optical design concepts, Librascope can offer an impressive capacity for achievement in the development of precision instrumentation. This knowledge, gained over a twenty year period, can be focused on *your* computer-control problem... with marked success! Your inquiry is invited.

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OTHER STANDARD MODELS AVAILABLE:

VOLTS	AMPS	REG.	MODEL
0-32	25	±1%	M60V
24-32	10	±½%	28-10WX
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5-40	30	±1%	MR 1040A
24-32	100	±½%	100 XA

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- **NO TUBES, MOVING PARTS OR VIBRATING CONTACTS**

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REGULATION: 5-32V Range: ± ½% for combined line changes of 105-125VAC and load of 0-15A. DC.
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Control ENGINEERING

JUNE 1957 VOL. 4 NO. 6

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

Published for engineers and technical management men who are responsible for the design and application of instrumentation and automatic control systems.

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Control ENGINEERING

A. Russell Aikman, coauthor of the analysis series article in this issue (page 105), is a past contributor to CtE and has often tendered his sage advice when questions arose concerning wet-process control. A native of England and a graduate of the University of Glasgow, Russ designed control systems for Imperial Chemical Industries, Ltd., London, before coming to this country in 1954. He now develops industrial instrumentation and investigates markets for same at Schlumberger Well Surveying Corp. Russ's contributions to frequency response theory are included in "Frequency Response," published in 1956; his extracurricular activities include chairmanship of committees in both the ASME/IRD and the ISA.

ABC | ABP

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While building more than 1,500 Y-4 bombsights for B-47 Stratojets, we improved original design, exceeded USAF specifications. Thorough testing at all stages of production assured perfect assemblies. *We delivered on schedule!*

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We make Hemisphere Sights for the MD-9 tail defense system in the B-52 Intercontinental bomber. This optical gunsight has a high degree of electronic automation. It calls for exacting manufacturing and environmental testing.

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The B-58 Hustler, the world's first supersonic bomber, carries a series of key assemblies engineered and produced by the Mechanical Division under sub-contract for Emerson Electric Corporation. Military security prevents detailed description of these ultra-precise electro-mechanical units.

CLASSIFIED

These are some of the men, recognized leaders in their fields, who head the integrated departments that team to provide complete systems service.

From the left: Dr. Howard H. Baller (radar and countermeasures, computers); Dr. Cledo Brunetti, Managing Director of Engineering, Research and Development (electronic design, automation); Donald F. Melton (nuclear handling, automation equipment); Dr. John E. Barkley, Director of Research (solid state, infrared); Zeke Soucek (seated), General Manager; Dr. Carl L. Kober, Director of Development (radar, infrared and inertial systems); Harold E. Froehlich (balloons and meteorological systems); Dr. Otmar M. Stuetzer (microwave optics, semi-conductor physics); Dr. Gottfried K. Wehner (behavior of metals in space flight).

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The top three United States Air Force jet bombers employ bombing or fire control systems produced in part by the Mechanical Division of General Mills.

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MECHANICAL DIVISION General Mills

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Minneapolis, Minnesota

SHOPTALK

We add Europe to our beat

About a year ago Derek Barlow, then working for Mullard Ltd. of London, invaded our editorial offices for the first time. He said he was interested in locating the outstanding users and manufacturers of automatic control equipment in this country so that he could compare their progress with that going on in Europe. After a quick briefing he vanished into the hinterland for several months, calling in occasionally for further leads. When he emerged he had a well-rounded view of industrial control in this country, plus an increasing interest in the publishing business and particularly in CONTROL ENGINEERING. As of this month Derek joins us as European Editor, stationed in London and responsible for keeping our readers up to date on control happenings both in England and on the Continent.

Derek is remarkably well-grounded for his new assignment, with a BSc degree in math, physics, and telecommunications, and a graduate degree in electronics. During the war he installed and tested radar equipment, and immediately after joined Rolls Royce to develop electronic equipment for measuring jet-engine performance. Next came a period as Chief Development Engineer for Wayne Kerr Labs, where he designed radar and navigational equipment trainers. Just before joining us Derek was technical/commercial engineer in charge of Mullard's product research, with prime responsibility for expanding activities in the industrial control field. His personal survey of both the European and American control fields gives him a good head start in his new job.

Palm trees, swimming pools, and control dynamics

Offhand you'd say that cocoanuts or bathing beauties don't have much to do with control dynamics, but that just isn't so, as you can see from this month's cover and *Industry's Pulse*, page 89. Not only do these signs of good living attract hard-sought-after engineers, but they attract companies too: it so happens that two of the largest missile and rocket test facilities are located in Florida and Arizona, areas where these desirable characteristics flourish. And these aren't the only "posh" places enjoying a control-plant building boom, as you'll find out next month when *Pulse* covers other new control centers.

FEEDBACK

PROBLEM FORUM

A Uruguayan subscriber who seeks bonus value from his subscription money has submitted a measurement problem to us. We mailed reproductions of his letter to several manufacturers and users who have solved similar application problems—result: each of them has sent him a solution, complete with literature references. Here are the problem and the most outstanding solution.

Try your problem in the forum. We will see that it gets the attention of experts by sending it directly to them. Through publication in this department, the most interesting problems and solutions will receive the scrutiny of our 31,500 readers, and will earn honorariums for their contributors.

Problem

To the Editor—

Thank you for the opportunity that you have given me of subscribing to Control Engineering, which comes to fill a great hollow that existed in our sources of information. I hope, with its help, to modernize our techniques.

Under my management is an electrolytic sodium chloride plant which, among other products, produces great quantities of sodium hypochlorite. I have tried to detect the final reaction of: $Cl_2 + 2NaOH \rightarrow NaClO + NaCl + H_2O$. I have used mostly pH and conductivity measurement but have not obtained signals that I could use for control or an alarm.

Some time ago I read in the publication "Industrial & Engineering Chemistry," (November 1954, page 71A), that the technicians of the Mathieson Chemical Corp. had developed a method which, based on the measure of oxidation-reduction potential, can control the above-mentioned reaction. In spite of having tried it several times, I have not been able to obtain any information this way.

Can you find a satisfactory solution to my problem?

Sadi Gomez Larcebo
Establecimientos Electronquimicos Electron
Montevideo, Uruguay

Solution

Mr. Larcebo—

The reason you were not successful with electrolytic conductivity measurements is that the conductance of the products of reaction differ not too greatly from the conductance of the unreacted products. That is to say, the break at the end-point would not be sharp enough to be of value.

You should have been successful with pH measurements, and the end-point can be determined by oxidation-reduction potential measurements. In fact, the "redox" potential is directly related to the pH. The earliest reference the writer has on this is by Müller[1], who gives the redox relation—

$$ClO^- + 2H^+ + 2e \rightarrow Cl^- + H_2O$$

and the potential equation—

$$E = E_o + \frac{0.0591}{2} \log \frac{[ClO^-]\,[H^+]^2}{[Cl^-]}$$

(at 25° C)

Since the concentrations of hypochlorite and of chloride are equal, the relation becomes—

$$E = E_o - 0.06\,pH$$

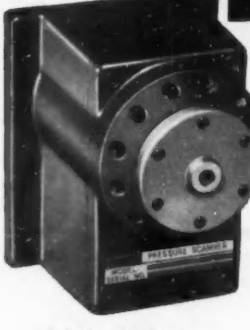
This equation simply states that the "redox" potential is a function of pH. The E_o value is given by Latimer[2] (corrected to reference to the saturated calomel electrode) as 1,135 millivolts. At zero excess of NaOH, or a theoretical pH 7, the potential then should be 735 millivolts. Müller gives a value of 760 millivolts. Pye[3], on some titration curves, gives values of 750 to 800 millivolts. Fisher and Carlson[4] give similar curves indicating about 750 millivolts.

The various authors emphasize the desirability of stopping the reaction with some excess NaOH unreacted in order to provide a stable solution. The end-point potential in these cases is a function of the original NaOH concentration, but the selected values are about 600 to 650 millivolts. We have confirmed this on several installations.

The electrode system used is a

Multiple Pressures with **ONE TRANSDUCER**

the New DATEX PRESSURE SCANNER*



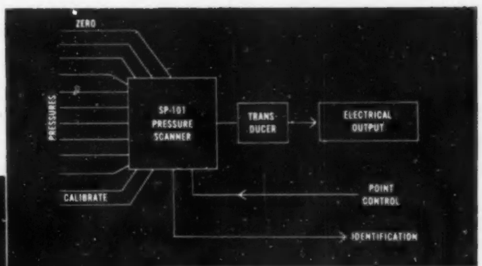
MODEL SP-101
PRICE $395.00

Designed to pneumatically switch a number of pressure sources into a single output port, the SP-101 Pressure Scanner introduces entirely new concepts into the field of pressure instrumentation. By providing an economical means of measuring a multitude of pressures, this device will accelerate the growth of automatic pressure recording in fields where it was heretofore economically unfeasible. Additionally, the pressure scanner not only reduces the number of transducers required for multiple pressure measurement but can be used to increase accuracy of measurement with presently available components. This is done by automatically introducing calibration and/or zero pressures during each recording cycle, permitting calculation of exact transducer response; and thus enabling greater measurement accuracy. Also, since the transducer is vented to atmosphere between pressure ports, hysteresis effects are minimized, contributing to greater measurement accuracy.

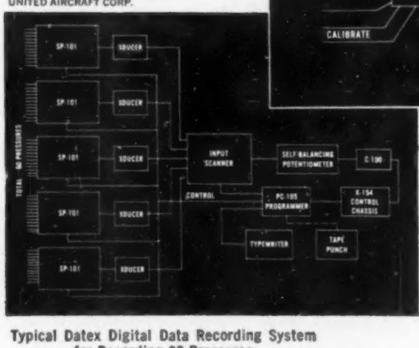
Basically, the SP-101 consists of a stator having 12 input ports, and a rotor that connects any one of the twelve input ports to an output port. The rotor is rotated to a desired position by a unidirectional high-torque motor, whose operation is controlled by means of a positive positioning arrangement. A relay circuit is incorporated in the unit to provide dynamic braking in order to stop the motor in a position where the rotor and stator ports are in coincidence.

The SP-101 Pressure Scanner can be used in applications that require the measurement of 12 pressures, all within the same transducer range. The unit can be externally programmed to switch pressures in any sequence desired, or it can be operated by means of a manual switch to select pressures to be measured.

TYPICAL SYSTEM USING ONE TRANSDUCER



*MANUFACTURED UNDER LICENSE FROM UNITED AIRCRAFT CORP.



Typical Datex Digital Data Recording System for Recording 60 Pressures

SPECIFICATIONS

FLUIDS:
Air and non-corrosive dry gases

PRESSURES:
From 0.1 psia to 350 psig

POWER:
50 watts, 115V a-c, 60 cycle

CONNECTIONS:
Input and Output–1/8"NPT

POSITIONS: 12

Designed for bulkhead mounting.

For additional detailed information, write for Bulletin SP-101-1.

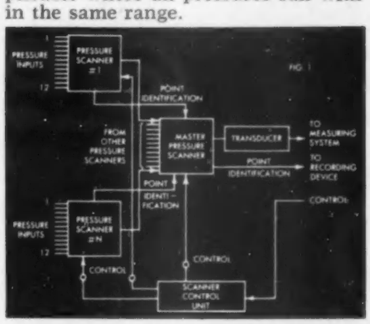
GIANNINI DATEX DIVISION

1307 South Myrtle Avenue, Monrovia, California

G. M. GIANNINI & CO., INC. 918 EAST GREEN STREET • PASADENA, CALIFORNIA

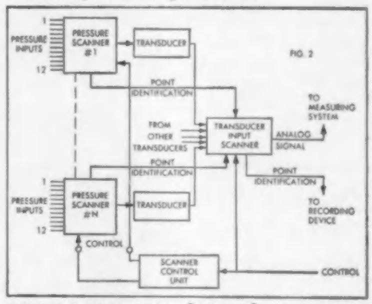
APPLICATION NOTES:

BY USING ONE pressure scanner to interrogate twelve other pressure scanners, as many as 144 pressures can be measured with only one transducer. A block diagram of a typical system is shown in Fig. 1. The 144 pressure inputs are connected to twelve pressure scanners. One output for each of these scanners will be connected to the input ports of an additional pressure scanner. The output of the latter scanner will thus sequentially scan the inputs of the 144 pressure variables. The aforementioned system is generally applicable where all pressures fall within the same range.



IN NUMEROUS APPLICATIONS, such as in engine test and wind tunnel operation, pressures vary over a wide range during the course of a recording cycle. With conventional multi-pressure recording systems, considerable measurement errors often result when the pressure drops to a small percentage of full scale.

IN ORDER TO ACHIEVE greater accuracy of measurement, the overall range is broken up into a plurality of smaller ranges. The SP-101 in combination with other Datex components can be used in an arrangement allowing the value of the pressure to be determined prior to measurement: permitting the appropriate pressure range to be selected so the optimum measurement accuracy can be provided.



WHERE A PLURALITY of transducer ranges are required, the input pressures are connected to the pressure scanner associated with the range which will offer greatest accuracy. This system is illustrated in Fig. 2. An increase in overall system speed is possible over that of the single transducer operation. As an example; assume a system containing ten pressure scanners that will be controlled in two groups of five each. While the transducers associated with the second group are being scanned, the first group is positioned to the next point. In this manner, the pressures of group number one are being stabilized while the transducers of group two are being recorded.

FEEDBACK

bright platinum for the measuring element and either saturated calomel or silver chloride for the reference electrode.

The concentration of hypochlorite resulting is a direct function of the caustic concentration used. On a continuous system of bleach preparation, it then becomes necessary to maintain a constant NaOH concentration.

1. "Zeitschrift Elektrochemie", 31, 323 (1925)
2. "Oxidiation Potentials", Prentice-Hall, New York
3. "Journal Electromechemical Soc.", 97, 245 (1950)
4. "Paper Trade Journal", May 7, 1956

W. N. Greer
Leeds & Northrup Co.
Philadelphia, Pa.

A place in the hearts of Americans . . .

To the Editor—

I subscribe whole-heartedly to the sentiments in your fine editorial (March issue) on Don Campbell. Rarely have I known a man with such a wide intellectual range, such insatiable curiosity, and so much confidence that human beings can accomplish anything if only they want to badly enough.

At the time of his death he was about to set out on another teaching and consulting tour of Europe. The enclosed letter from Dr. Turpitz gives some indication of the high esteem he enjoyed abroad as well as in this country.

P. S. Buckley
E. I. du Pont de Nemours & Co., Inc.
Wilmington, Del.

. . . and Europeans

P. S. Buckley—

All of us over here are deeply moved by the sudden and unexpected death of Professor Campbell. We have held a celebration in his honor, in which about 70 persons in leading positions of German industry have taken part. As we had nobody to replace Professor Campbell in such a short time, we listened to his voice from the tape on which his speeches were recorded, and we shall give a copy of his papers to all our participants.

We are planning to commemorate Professor Campbell by installing his bust in the hall of the house of our society. I would be very much obliged to you, if you were so kind as to send me presently some photos of him, for we intend to publish among German industrialists some obituary notices.

I would be most obliged if you could also let me have a short *curriculum vitae* of Professor Campbell.

Dr. Turpitz
Internationale Studiengesellschaft
Wiesbaden, Germany

Like gold, accuracy is where you find it.

To the Editor—

The news story on the Esso-Belot logger-computer which appeared in your March issue stated that the accuracy of the computed operating guides was plus or minus two percent. I should like to point out that this tolerance is based on accurate input data and does not include errors that may exist in the primary instrumentation. Any inaccuracies in transducing devices, etc., must, of necessity, be excluded in a consideration of the error attributed to the combination automatic data logger and analog computer.

C. H. Taylor
Fischer & Porter Co.,
Hatboro, Pa.

Reliability pitfalls await unwary . . .

To the Editor—

I have read with interest the article on reliability by Dr. Obert B. Moan, appearing in the Data File of the April 1957 Control Engineering. The article indicates the large improvements in reliability that can be gained by using redundancy. However, there are a number of simplifications, made by the author, that invalidate many of the results:

1. The author assumes that failure of a component is equivalent to the removal of that component, i.e., after the component has failed, its failure does not affect the remainder of the equipment. This is almost never the case. For example, if the component is a switch, the contacts may become permanently closed; if the component is a vacuum-tube amplifier, heater-cathode shorts or failures in the decoupling circuits can cause false signals in the output. Therefore, the author's statement that "reliability . . . approaches 1 if the number of . . . parallel branches increases without limit" is incorrect. On page 99 of the April issue, the statement that the reliability of n groups of k parallel components (Figure 2) "is much more effective than the system shown in Figure 1" is misleading. Similar comments apply to Figures 3 and 4. Careful analysis indicates the presence of optimum values for n and k, such that

increases in k (for a given n) beyond the optimum lead to poorer reliability.

2. The author assumes that the wires or connectors used to accomplish parallel connections are fully reliable. However, recent surveys by RETMA and others indicate that wires and connectors are often less reliable than resistors. In addition, there are few cases in which parallel connection with *only* wires and connectors is possible. For example, when two vacuum tubes are connected in parallel, additional parts must be added to suppress parasitic oscillations. Again, the statement "reliability . . . approaches 1 if the number of . . . parallel branches increases without limit" is incorrect.

I believe that Dr. Moan is aware of these limitations; however, they should have been stated in the article.

Oscar Lowenschuss
Sperry Gyroscope Co.
Great Neck, N. Y.

. . . if he doesn't read the whole story

To the Editor—

The introduction and title of Data File #2 presented in the February issue as "Reliability of Redundant Systems" should apply to Data File #4 in the April issue and Data File #5 in the May issue. It states: "The reliability values . . . are the maximum possible. They do not reflect the degradation that will occur in specific applications. The user should exercise his judgment in the light of the following considerations:

1. Will the failure of any component or subsystem affect the others?
2. How much will redundancy increase weight, space, and cost and maintenance?
3. How about added complexity?
4. Will concealed component failures require special testing techniques to locate faulty parts and assemblies?"

Mr. Lowenschuss is doing what I suggested, exercising his judgment in the light of the above considerations, when he states that there may be optimum values for n and k.

Mr. Lowenschuss also objects to an assumption that wires and connectors used to accomplish parallel connections are fully reliable. Mr. Lowenschuss is incorrect; that is his assumption, not mine. He has interpreted my block diagrams as indicating electronic block diagrams wherein the blocks represent electronic components and the interconnecting lines represent wires and connectors. The blocks do indeed represent components, but these components are any components of the system under analysis; for a hydraulic system they would be valves, regulators, accumulators, pumps, motors, or even piping if the reliability of

FEEDBACK

the piping is a factor to be considered; for a mechanical system they would be gears, linkages, detents, etc.; for an electronic system they would be electronic components, but would include wires and connections as blocks. It is then only necessary for the user to feed his reliability values for the wires and connectors into the formulas presented.

O. B. Moan
Missile Systems Div.
Lockheed Aircraft Corp.
Van Nuys, Calif.

Does pessimism breed socialism?

To the Editor—

It is not the number of trained engineers or technicians but uses made of their knowledge and skills which count.

In the electric utility business some companies are not as efficiently operated as other companies due to top management's refusal to accept recommendations from its engineering staff.

Tick off on your fingers the number of government-operated businesses of one kind or another and see if you can find any one as efficient as the average privately-owned business.

From all the reports received the Russian Commissar or head of a business is selected primarily on basis of standing in the party rather than engineering or technical ability .

Why so damned pessimistic? We do not need to fear a lack of skilled personnel as much as we do creeping socialism.

D. E. Woods
Central Power & Light Co.
Corpus Christi, Tex.

Second installment

To the Editor—

To present up-to-date information on the equipment we manufacture, I would like to submit the following, as an adjunct to my letter published in your May *Feedback* section:

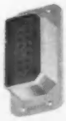
The Datex Div. of G. M. Giannini & Co., Inc., not only manufactures the model C-100 encoder shown in the tabulation (p. 116, "Analog-to-Digital Converters", CtE, April 1957), but manufactures a whole series of encoders and geared encoder combinations to produce outputs of from 64 counts to 1 million counts. All encoders are brush-type, wherein the brushes are always in contact with the encoding disc. All encoders can be read without the encoder being stopped, and the frequency of readout is limited primarily by the ca-

are you fighting SPACE?

No need to suffer from engineering claustrophobia, if you design with CANNON PLUGS in mind!

DIC Coaxials. Screw-type coupling Low VSWR. for 50-, 70-, 93-ohm cable

K Miniatures 3 to 50 contacts 13 different arrangements



DP Type Rack-panel-chassis style 7 to 40 contacts

MC Sub-Miniatures 3 & 6 contacts Built for rugged use

D Sub-Miniatures 9 to 50 contacts Same space... same weight!

Cannon Miniature and Sub-Miniature Plugs are rugged, easy mating, unusually versatile, neat and compact. When you design with Cannon Miniatures in mind you'll get complete electrical circuit dependability in a very small space. Up to 50 contacts in ½ or ⅓ the area taken by standard multi-contact connectors!

Rectangular and circular types. Hermetically sealed, vibration and moisture resistant, and general purpose designs. Contacts for 5, 10, 15, 25 amps...and miniature coaxial connectors. Practically all five ampere contacts are gold plated. High dielectric insulation in phenolics, resilient materials, glass seals, Zytel, Diallyl Phthalate and Melamine. Aluminum alloy or steel shells, depending upon application.

Miniature lines include: DPA, DPX, DPM, DPG, K, MM, MR and Diamond MB and SM Coaxial connectors. **Sub-miniatures:** D, MC, and Diamond DIC Coaxial connectors.

Write TODAY for new 32-page 2-color Miniatures Bulletin HMC-2. Also, write for Bulletin SM-1, "Soldering Small Contacts."

For an interesting discussion of the broad subject of "Reliability," write for Cannon Bulletin R-1.

CANNON PLUGS

WHERE RELIABILITY IS THE 5TH DIMENSION

AWARENESS OF PROBLEM · INTEGRITY OF INTENT · DESIGN EFFORT · MANUFACTURING CONTROL

Please refer to Dept. 422

CANNON ELECTRIC CO., 3208 Humboldt Street, Los Angeles 31, California. Factories in Los Angeles; Salem, Massachusetts; Toronto, Canada; Melbourne, Australia; London, England. Manufacturing licensees in Paris and Tokyo. Representatives and distributors in all principal cities.

pabilities of the readout device and the input circuit to the encoder. With proper design of input circuits we believe our encoder can be read out as many as 100,000 times per second on a sampling basis, or continuously where dc is used to operate the readout circuit.

John W. Bodnar
Sales Manager
Datex Div.
G. M. Giannini & Co., Inc.

Newer converter models were not included in table because of inevitable time lag between article preparation and publication. Ed.

Reader finds lost Z . . .

To the Editor—

Referring to the February '57 edition of Control Engineering, page 102, Table III, Equation 13 ("Sampled-Data Systems", Donald J. Gimpel), I believe that if

$$f(t) = \cos at,$$
$$F(z) = \frac{z(z - \cos a\,T)}{z^2 - 2z\cos aT + 1}$$

H. Schemm
Campbell Soup Co.
Upper Darby, Pa.

. . . and loser claims it

To the Editor—

Regarding the correction to the Z transform, Item 13 in Table III, the equation is now not correct. The correct version is the one suggested by one of your readers.

D. J. Gimpel
Panellit, Inc.
Skokie, Ill.

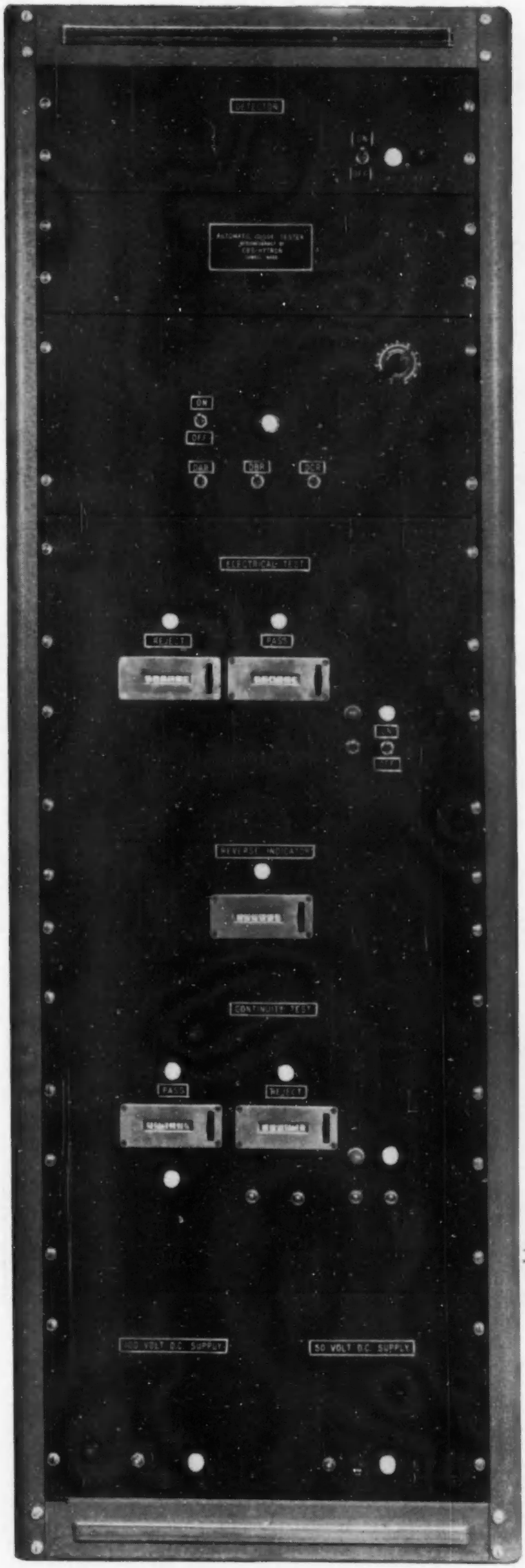
Wants article index

To the Editor—

Our firm has bound the complete set of your magazine, Control Engineering, for 1956 into book form for ready reference. For use in connection with this book, we would appreciate it if your office could furnish us with an index of all the articles printed in 1956, arranged alphabetically by subject. Such an index would be of immeasurable help to our engineers.

Dasol Corp.
New York City

Index for all technical articles, news items, editorials, and Industry's Pulses published during 1956 starts on page 183 of the December '56 issue. Author index appears on pages 189 and 190 of the same issue. If you need separate reprints of either index, write Mrs. Florence Baxley in our office. Ed.



WHAT... NO METERS?

NO METERS ON THIS PRECISION TEST STATION
. . . only electrical counters? That's right and there is a very good reason. This crystal diode tester is automated and meters could not keep pace with its speed, up to 1500 diodes an hour.

Matched to CBS-Hytron's completely mechanized diode production, the versatile unit tests the output of six integrated machines. Its five positions check continuity, accidentally reversed polarity, and a variety of electrical measurements. Accuracy, with the element of human error eliminated, surpasses that of manual testing and assures you of a minimum of line rejects.

You can depend upon this modern equipment to put your crystal diode quality control on CBS-Hytron's production line . . . and to double-check for you the quality built-in by CBS automation. Take advantage of Advanced-Engineering like this. Specify CBS glass diodes for uniform . . . dependable . . . automatically controlled quality.

←

CBS AUTOMATIC DIODE TESTER. Panels (top to bottom) are for: sensing detector • one-volt reverse power supply • bridge testing networks (3) • relay switching circuits for electrical tests (pass and reject counters) • reverse polarity indicator (reject counter) • continuity tester (pass and reject counters) • reverse and relay power supplies.

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A Division of Columbia Broadcasting System, Inc.

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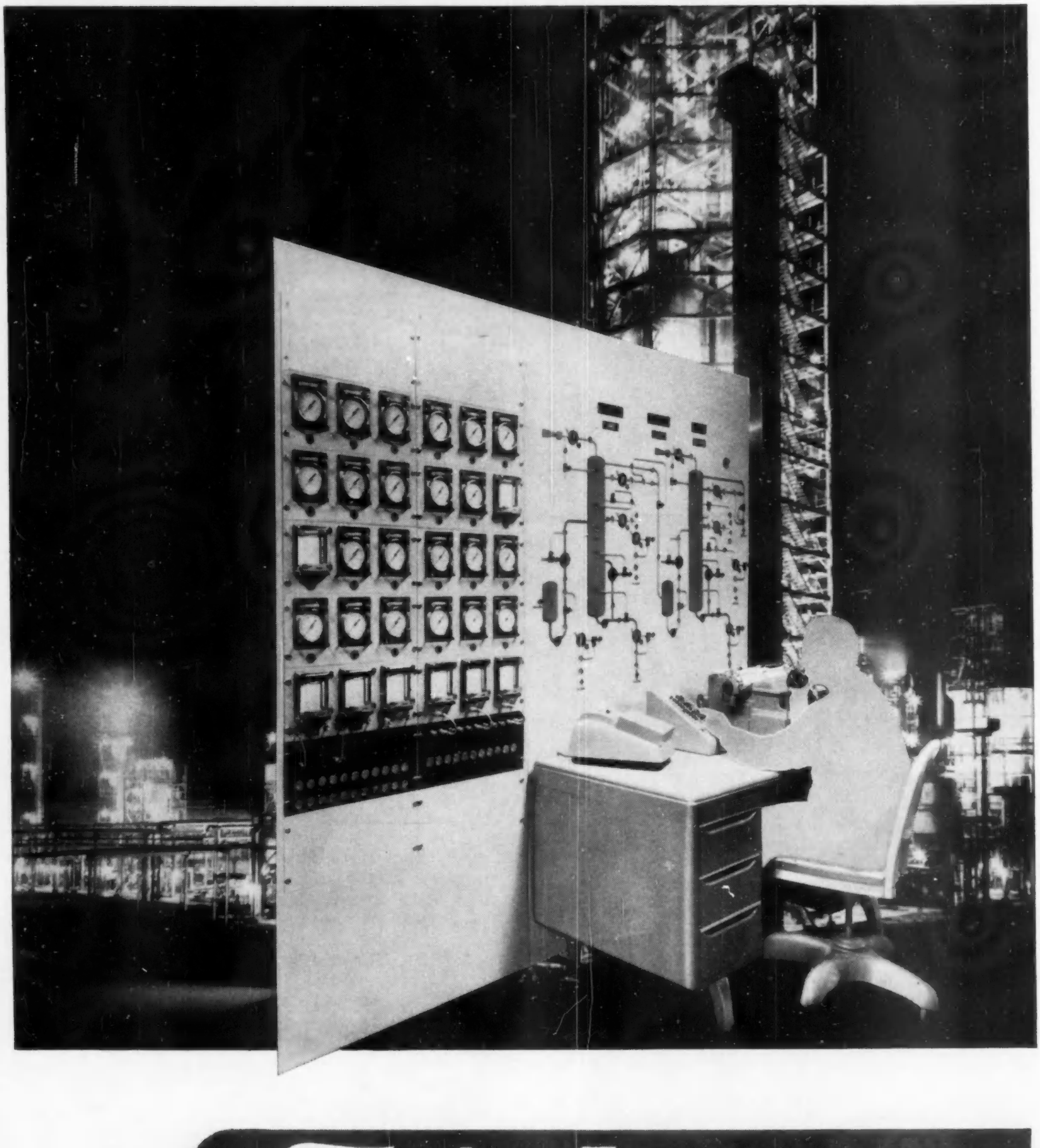
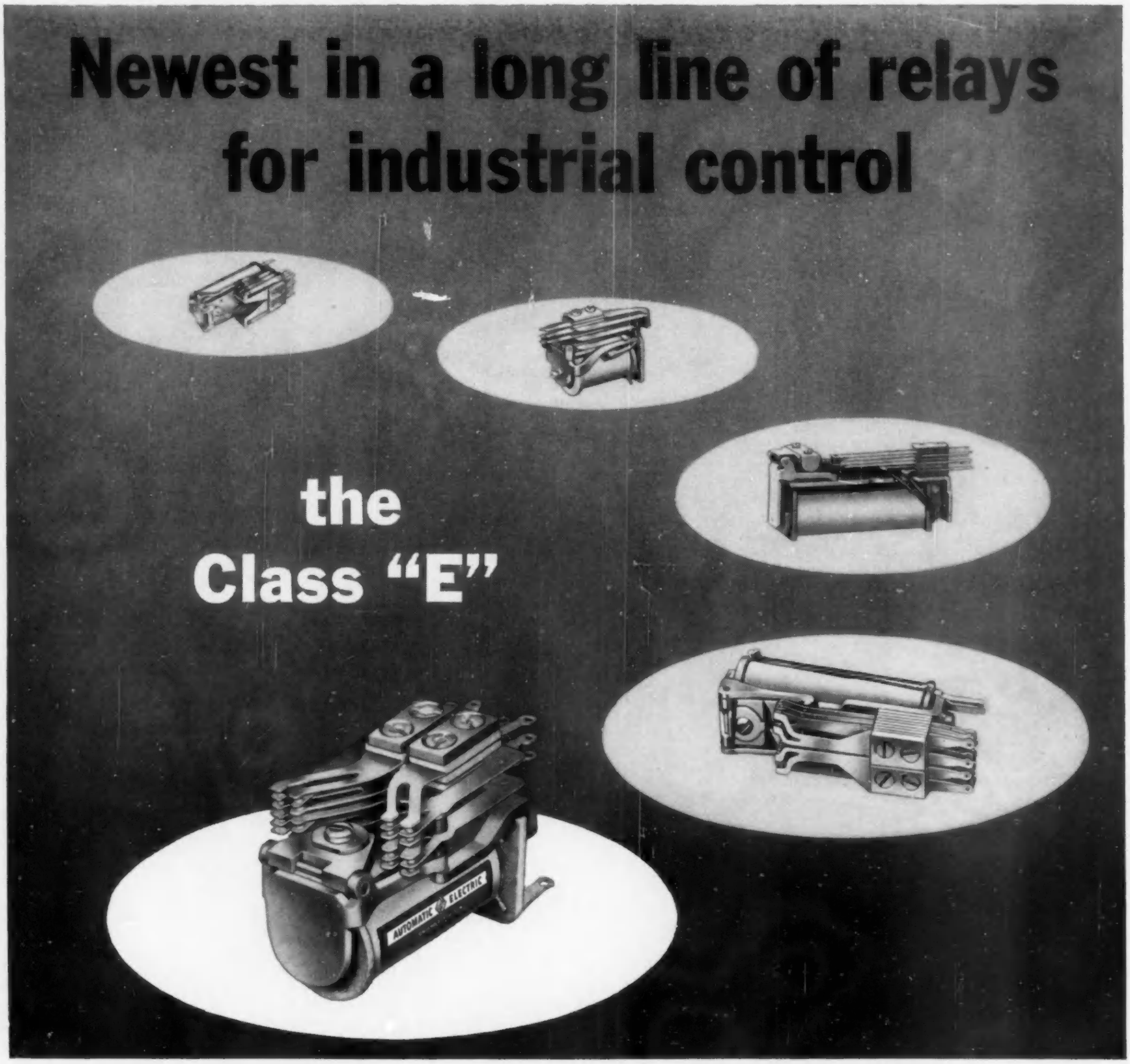


Taylor Instruments



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This new miniature relay comes to you with a solid reputation, backed by 65 years of leadership in automatic dial telephone equipment for America's Independent telephone companies and leadership in industrial controls for industry.

Check these features of the new Class "E"—

- miniaturized, telephone-style, base mounting for rear-connected wiring.
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- heavy-duty backstop that won't wear out.
- adequate terminal clearances for easy wiring.
- long-life, lubricant-retaining bearing also allows for an easy check of the heelpiece airline setting, without disturbing the adjustment.
- fully independent twin contact springs.
- sturdy, strain-relieved heelpiece insures stability of adjustment.

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AUTOMATIC ELECTRIC

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GENERAL SYSTEM

ONE OF AMERICA'S GREAT COMMUNICATIONS SYSTEMS

JOSEPH M. HARRER **pioneers atomic power**

When Joe Harrer joined the Tennessee Eastman Corp. in 1943, he didn't know what the company was making. But he was intrigued by the complexity of the control problems in the process that was sketched out for him. And the facilities that were available in Oak Ridge were a tempting lure for a young engineer who was eager to learn. It wasn't until President Truman made his historic statement after the bombing of Hiroshima that Harrer knew where the end-product of his electromagnetic separation process was going. That was Joe's first indication that he was in the atomic business.

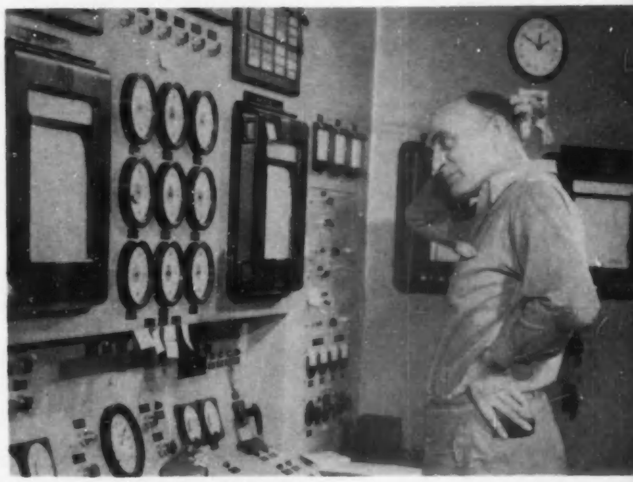
By 1946, the separation of uranium had developed into a routine operation, so control specialist Harrer arranged to have himself transferred to the Daniel Power Pile Project, a curious band of dedicated men with a challenging problem: to design the world's first nuclear reactor to generate power!

Work on the Daniel project led to a spartan life, Joe recalls—study 16 hours a day, six and seven days a week. But by the end of 1947, the group had done what many scientists believed was impossible. They had a finished design on paper. Harrer's contribution consisted of designing the reactor-control system, including the electrical control instrumentation and the mechanical components. In addition, he designed a kinetics simulator for analyzing reactor flux.

At least one member of the group was impressed by the work of the project and Harrer's part in it. He was a hard-bitten, intense Navy captain, H. G. Rickover. When Rickover sold the atomic submarine concept to the Navy, and development was assigned to Argonne National Laboratory, Harrer went along to Lemont, Ill. His first job: to organize an instrument and control section for the newly activated Naval Reactor Div., whose first project was to be an atomic power plant for the submarine *Nautilus*.

With the *Nautilus* design completed, Harrer continued his pioneering. He initiated work on the oildag Boron Coating Process at ANL, a technique for producing better control rods. He set up a semiproduction process for coating all types of chamber electrodes at the laboratory with this technique. He started the ANL program for design of higher current chambers and associated measuring circuits (in this project, he established the feasibility of using duplex chambers with two proportional signals). And he began a program leading to the construction of an improved type of continuous red-positioning system for general reactor application.

None of his classmates at Rensselaer Polytechnic Institute realized that Joe Harrer had the pioneering bug when he graduated with a BSEE in 1934. His



first job was in electrical power construction. In 1935 Harrer got his initial taste of control work when he joined E. I. du Pont de Nemours & Co., Inc., to do instrument and control-system maintenance. In 1940, he joined Bausch & Lomb Optical Co. to design and operate electrical systems for industrial process control. Three years later rumors from Eastman engineers about the tough control problems there persuaded Harrer to move to Oak Ridge.

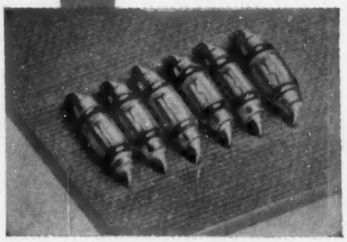
Despite the heavy work load at Argonne, Harrer found time for graduate courses in electrical engineering at Illinois Tech, earning a MSEE in 1952. During the recent dedication of the Experimental Boiling Water Reactor (CtE, April 1957, p. 23) Joe narrated the best part of a three-hour closed-circuit television show just as if he was a hardened veteran of show business. At home, Joe Harrer is a oneman representative in a female world; he's surrounded by women: wife Suzanne, daughter Lora (21), daughter Nancy (15), and daughter Elizabeth (6).

Although atomic power is a fact today, Harrer is still pioneering. He designed instrumentation and control for the first U. S. atomic power plant built solely to generate electricity, the EBWR (see page 149) and is now responsible for getting the first actual operating data for such a unit.

According to Harrer, "Reliability is our biggest deterrent. Commercially available equipment just isn't reliable enough, and that includes instruments, control valves, and circuitry. If atomic power is going to move ahead rapidly, these things have got to be more reliable." And with that, Joe Harrer gets that pioneering gleam in his eye.

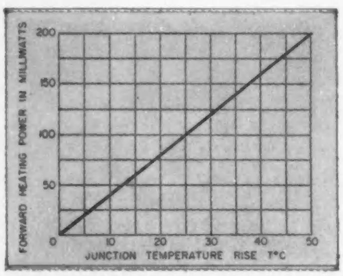
New Sylvania package offers

Maximum Dissipation in Miniature Diodes



Cooler operation resulting from higher dissipation of Sylvania glass-to-metal miniature diode permits closer printed board spacing for maximum savings in space.

Right angle bending of leads for printed board insertion does not affect the diode body since metal-to-glass design avoids chipping or cracking.



Typical dissipation curve of the Sylvania glass-to-metal diode.

Actual comparison of Sylvania miniature diodes with all-glass miniatures shows that the Sylvania metal-to-glass package design results in greater dissipation. As a result, cooler operation can extend diode life and improve product dependability and performance. Diodes can be banked closer on printed circuit boards for maximum space savings.

Metal-to-glass package offers other important advantages. The diode cartridge is assembled *before* installation of the whisker and die—avoiding excessive heating. In addition, right angle bending of the leads for printed board insertion does not result in chipping or cracking of the diode body.

Sylvania offers a complete line of miniature diodes in the glass-to-metal package. The package meets the standard RETMA outline of .105″ maximum diameter and .265″ maximum overall length. Write for complete details.

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13 Information Systems Service New Tidewater Refinery

- **$180,000,000 refinery gives automatic data logging its biggest test to date. Thirteen separate systems have a capacity of 4,600 points.**
- **Modifications to Panellit 605 information systems increase versatility—each system performs three prime functions.**
- **Production Dept. counts on million-dollar data systems to help operators keep refinery running under best conditions.**

Automatic data logging appeared last month in its biggest application to date when Tidewater Oil Co. started up a brand new 130,000-barrel-per-day refinery at Delaware City, Del. Tidewater, which has never used such automatic equipment before, invested over a million dollars in 13 separate information systems, each built around a Panellit 605 dual function information system (CtE, Sept. '55, p. 83).

When Tidewater's management decided to close its Bayonne (N. J.) refinery and start from scratch to build a new one, it determined to turn out the most modern refinery possible. One thing top management was sure it wanted: automatic data-logging equipment.

Panellit started design of the information system two years ago, working with Tidewater and consulting engineers C. F. Braun & Co. The oil company wanted the systems to perform two jobs: 1) to help unit supervisors obtain actual values of key measurements for every shift, and 2) to supply data for plant-management control.

• **Thirteen systems**–The photo above shows how the information systems are spread throughout the refinery layout, biggest ever built at one time. There's a data system associated with every major step in the refinery process: 1) the crude unit, 2) the fluid coker, 3) Orthoflow fluid catalytic cracker, 4) gas plant, 5) polymerization plant, 6) alkylation plant, 7) catalytic reformer, 8) Udex extraction unit, 9) catalytic desulfurizer, 10) hydrogen unit, 11) sulfur recovery plant, 12) refinery utilities, and 13) the tank farm.

Added up, the systems have a capacity for logging 4,600 points. But automatic data logging is only part of the requirements. Each system has three important functions:

- automatic data logging of process variables at specified periods or upon demand of operator.
- automatic scanning of variables which are printed out only if they stray from defined limits.
- automatic integrating of selected variables for the Accounting Dept.–read out on both typewriter and punched tape.

In the automatic data logging system, Panellit has increased the amount of corrected data that is recorded by using devices that perform square root, addition, and other simple mathematical operations. To optimize the logging operation a study was made determining what calculations could best be made right in the control rooms of the refinery units and what

REFINERY . . .

STORY STARTS ON PAGE 25

calculations should be performed in the centralized computing facility with the IBM 650.

• **Accounting points**—One unique addition to the standard Panellit 605 system is the logging of so-called accounting points. Panellit has added a bank of integrators to total up variables that are important to the refinery's Accounting Dept. Once a day—or as frequently as the Accounting Dept. wants—these key totals are logged first on the automatic typewriter, then on punched tape, which is converted to punched cards to fit Tidewater's accounting equipment and for processing on an IBM 650 computer.

Still another innovation is found in the tank-farm information system. Panellit has incorporated a special-purpose digital computer into the system to supply corrected data instead of raw measurements. In each of the 88 tanks, there is a means for measuring electrically both liquid level and temperature, the latter taken at four points and averaged. These two variables for every storage tank can be indicated by digital readout on the operator's console (at the flick of a switch) or can be fed into the computer where tank level at the measured temperature is converted into volumetric contents and corrected to standard conditions.

Before the refinery was opened, each tank was "strapped"* with water, and the measured characteristics stored in the memory unit of the computer. Tidewater claims its refinery has the only tank farm in the country in which an operator can determine accurately the contents of all the storage tanks from the console.

One other innovation claimed by Panellit is a new patented preprinted log sheet—it's said to be the first one set up to follow the process, reporting variables from start of flow to output, rather than grouping together variables of the same kind.

• **Production's viewpoint**—With installation completed, Tidewater's management is anxious to see what the new information systems can do. To Tidewater's production department, the continuous scanning function is even more important than automatic data logging. Assistant Manager of Refinery, James McDonald—who is more interested in operation than instrumentation—points out that a refinery operator is really a human scanner. But human scanners get tired, have other responsibilities, and can't watch every minute. Continuous scanning by automatic equipment should eliminate a lot of oversight and error, he says.

McDonald is also optimistic about scanning's ability to help keep the process operating at the best conditions. He feels that small percentage savings add up quickly when a plant gets as big as the Delaware City refinery. McDonald offers cooling water as a typical example. With cooling pumps requiring 18,000 hp, he figures there's a big saving to be collected if power can be reduced only 10 percent by making better use of the cooling water.

The constant automatic scanning system, says McDonald, will warn the operator as soon as temperatures

Strapping refers to the old oil industry custom of measuring the tanks of a refinery with metal tape or strap to determine accurately how many gallons a tank would hold at all levels. Strapping with water means obtaining the same information by measuring the volume of water pumped into a tank to reach specified levels.

Bell Laboratories researchers Henry S. McDonald, Dr. Eng. from Johns Hopkins, and Max V. Mathews, Sc.D. from M.I.T., examine magnetic tape used in new research technique. Voice waves are converted into sequences of numbers by periodic sampling of amplitudes, 8000 samples per second. General purpose electronic computers act on these numbers as a proposed transmitting device might.

They send real voices on imaginary journeys

In their quest for better telephone service, Bell Laboratories researchers must explore many new devices proposed for the transmission of speech signals. For example, apparatus can be made to transmit speech in the form of pulses. But researchers must always answer the crucial question: how would a voice sent through a proposed device sound to the listener?

In the past it often has been necessary to construct costly apparatus to find out. Now the researchers have devised a way to make a high-speed electronic computer perfectly imitate the behavior of the device, no matter how complicated it may be. The answer is obtained without building any apparatus at all.

The researchers set up a "program" to be followed by the computer. Actual voice waves are converted into a sequence of numbers by sampling the waves 8000 times per second. Numbers and program are then fed into the computer which performs the calculations and "writes out" a new sequence of numbers. This new sequence is converted back into real speech. Listeners hear exactly how well the non-existent device could transmit a real voice.

With this novel technique, new transmission ideas are screened in only a fraction of the time formerly required. Thus valuable time and scientific manpower are saved in Bell Laboratories' constant search to provide still better service for telephone customers.

BELL TELEPHONE LABORATORIES

World center of communications research and development

WHAT'S NEW

REFINERY . . .

STORY STARTS ON PAGE 25

leave the optimum range. And even more important, it will print out in red off-normal readings and the time they occurred—providing a permanent record that a supervisor can check. With manual logging, it would be up to the human scanner to spot any undesirable change in temperatures. But manual logging takes up to 40 min of each hour just for recording readings; operator's opportunity to notice temperature deviations are limited to one or two an hour.

• **Problems**—Biggest problem in introducing automatic data-logging equipment to the Delaware Refinery was selling the operation of automatic equipment to the men in the control room. That's what Delaware Refinery's instrumentation coordinator Ed Roth reports. Experienced operators are used to a lot of big recorders and hand logging; it takes a while to overcome their inertia. To help speed up the process, Tidewater and Panellit are preparing a special operators' school that will teach control-room men how to use the automatic equipment and what it will do for them.

Although the information systems are the highlight of the instrumentation at Delaware City, all other kinds of instruments and controls are in use there, too. Tidewater estimates that it has invested a total of \$7½ million in process instrumentation and control; the oil company provided overall instrumentation supervision and set up the functional requirements, while C. F. Braun & Co. specified the actual hardware. The bulk of the business was divided this way:

► Board mounted controllers—Foxboro

► Blind potentiometers—Bristol.

► Field-mounted instruments (transmitters)—Taylor

► Ac counting meters and flow meters—Taylor-Barton

► Control valves—Fisher Governor

One interesting aspect about the operation at Delaware City is the instrument maintenance contract between Tidewater and Panellit Service Corp. (CtE, March '57, p. 38). According to PSC Vice-President Neil Blair, his company supplies personnel and supervision for maintenance, scheduling, and other maintenance department activities, while Tidewater supplies facilities. Ed Roth is responsible for coordinating refinery activities into this maintenance setup.

ADSMANSHIP HANDBOOK

Chapter VI; Volume I

THE AD THAT DARED TO COMPARE

COMPARE THESE MODELS!

OUR MODEL

OSCAR Model J

SOME OTHER MODEL

Model Kay

The Model J is designed specifically for rapid and accurate reduction of trace records appearing on either film or paper. Output range is from 000 to 999 with an accuracy of 0.1% of full scale. Featuring high reliability and simplicity of operation, the Model J automatically applies linear and non-linear calibration factors to amplitude measurements.

This model is designed for just about anything but rapid reduction. It does reduce occasionally but certainly not with any degree of accuracy since it avoids any type of scale. Output range: unpredictable. Record handling capabilities limited to LP only. Convenient packaging (chassis measurements: 36-24-34½) makes operation easy.

An ad, dying to draw a comparison between its model and some other model, mistakenly chose for comparison a curvilinear coordinate job with universally basic built-in features. Comparison was pure havoc. MORAL: Comparative analyses are fraught with fallacies.

Another in the series of adsmanship parables provided as a public service by the Benson-Lehner Corporation. You'll be interested in Benson-Lehner's growing line of data reduction equipment . . . there'll be a new machine every month this year. For information re: data reduction, write:

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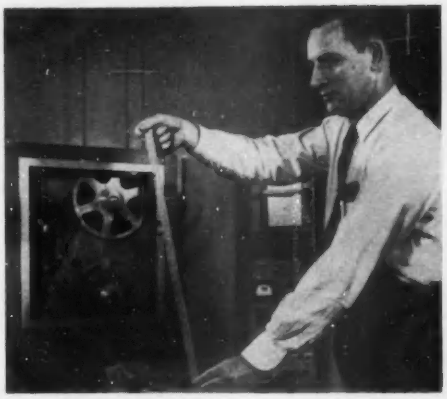
BENDIX NUMERICAL CONTROL . . .
For Kearney & Trecker bed-type mill was built for Martin Co., which will use it to mill missile and aircraft parts.



PUNCHED TAPE . . .
with process information is input to computer. Second punched tape* is output of computer and input to machine control.

HYDRAULIC SERVOS . . .
one on each lead screw position workpiece and cutter.

Numerical Control Forces New Machine Tool Concept

Last month Bendix Aviation Corp. put the finishing touches to a numerical control for a Kearney & Trecker three-dimensional milling machine, the first production application of a punched-tape control system for a 50-ton machine tool. Significant though the application was, control engineers found the approach even more so. Bendix designed the controls and served as prime contractor; K&T built the machine tool to Bendix specifications and requirements.

Instead of applying its numerical control to a standard machine tool, Bendix first worked with K&T to change critical components of the bed-type mill. The objectives: to design for dynamic response and to increase the mill's stiffness.

• **Systems approach**—Key to Bendix's efforts, according to control engineer C. B. Sung, is the use of an integrated design concept, the systems engineering approach. He explains it this way: "As we see it, there are two ways you can build numerically controlled machine tools: start from scratch as we did on the K&T bed mill, or modify the machine tool design so that the finished product has improved response. But in either case, you have to use an integrated design concept.

"Basically," Sung continues, "the usual machine tool does not have sufficient stiffness; its inertia is too high or not properly distributed; there's too much backlash and too much friction."

• **Trouble spots**—The first step in redesign, Sung says, is to look for proper distribution of inertia, friction, and compliance (the reverse of stiffness). He sees four or five key trouble spots on the average machine tool:

*Magnetic tape in rear of photo is auxiliary memory storage unit for computer.

gearboxes, lead screws, rack and pinions, friction of the ways, and the amount of backlash and where it occurs. The drive motor, Bendix points out, is a basic part of the system; if its response is low, there's not much you can do with the entire machine to get high response.

• **Bendix design**—On the K&T bed mill, Bendix uses a punched-tape input to a computer which determines position and speed information. The output of the computer, a second punched tape, serves as input to the machine tool control. To get continuous operation the machine tool reader reads several blocks of punched tape input at one time, storing them until the tool is ready to use them.

Feedback is accomplished by a Bendix Quantizer, a pulse generator that takes readings right off the lead screw. There's one unit on each of the three lead screws. Hydraulic servos with Bendix valving provide the "muscle" for the machine tool.

The first unit was built for the Martin Co. Now Bendix is working on 22 additional numerical control units for K&T traveling column mills, ordered by the Air Materiel Command for aircraft builders. The same systems approach is being used to develop the machine tool numerical control combination for these mills, too.

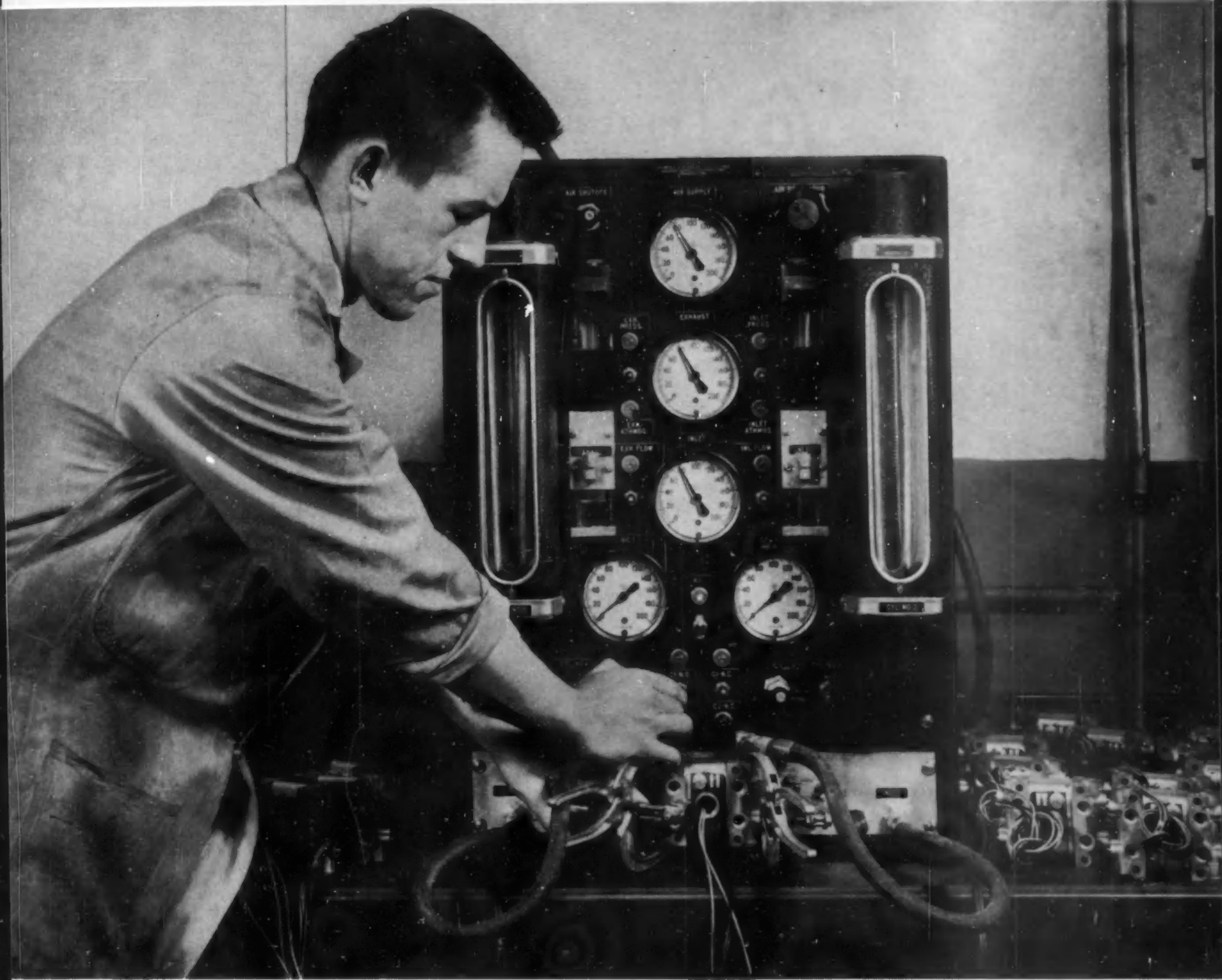
AIEE Plans Feedback Panel

One of the highlights of the coming AIEE Summer General Meeting (Montreal, June 24-28) is a special panel discussion on "Objectives and Trends in Feedback Control Systems Progress", scheduled for June 26 at 8 pm. Broad representation of industry is included in the panel:

Gordon S. Brown—MIT
S. W. Herwald—Westinghouse Air Arm
O. E. Orbom—Allegheny Ludlum Steel
Don P. Eckman—Case Institute
Harry Palmer—GE
E. M. Grabbe—Ramo-Wooldridge

Led by chairman Harold Chestnut, the group will first take a look at what feedback progress has been made in the past ten years and then sample what's currently happening with feedback technology in these fields:

Education—Brown
Military and Industrial—Herwald
Computer and Business—Grabbe
Chemical and Industrial—Eckman
Heavy Industry (users)—Orbom
Industrial Manufacturing—Palmer



WHAT'S NEW

Harvard Switching Symposium Draws International Specialists

How fast the field of switching theory is progressing was indicated in April, when 900 specialists from all over the world flocked to Cambridge, Mass., for an International Symposium on the Theory of Switching, sponsored by the Computation Laboratory at Harvard University.

Just 10 years ago no one would speak of a "theory of switching", even though Shannon's paper showing the use of Boolean algebra in the design of relay nets had appeared before World War II. Then, the intuition of the engineer was sufficient to enable him to devise a suitable net for whatever purpose was required. He would have been the last to expect that Boolean algebra would be useful in simplifying his problem.

It's debatable how much assistance engineers have derived from Boolean algebra to-date. But control circuits are becoming more complicated. At some point, the specialists theorize, intuition fails or becomes unreliable.

• **World-wide interest**—The attendance of 900 is strong evidence that there is interest in the subject. The program for the Harvard symposium included names from Switzerland, Spain, Belgium, the Netherlands, Sweden, Yugoslavia, Germany, Czechoslovakia and U.S.S.R. Four Russian representatives—Gavrilov, Lunts, Povarov, and Roginskii—were scheduled

What They Said

Here are some brief comments on a few of the papers presented during the Harvard Switching Symposium:

PROF. JOSE GARCIA SANTESMASES (University of Madrid) reviewed historical developments of switching devices in Spain. He briefly described research on ferroresonant flip-flops as switching devices.

JAN A. RAJCHMAN (RCA) discussed the state of the art of switching logic. He described some recently developed devices such as the transfluxor and the perforated ferrite plate memory matrix, and expounded on the "current-steering" principle by which signal-to-noise ratio in core matrix switches can be improved.

PROF. S. H. CALDWELL (MIT) outlined the problems in realization between the theorist and the gadgeteer, or, more specifically, between the logic designer and the switching-circuit engineer. He also described the concepts of transistor switching circuits, suggesting that the bilateral transistor will be found useful in more complex switching circuits and predicting that hybrid circuits will find significant application in the future.

PROF. R. C. MINNICK (Harvard) commented on the possible use of a two-word-length multiply or divide accumulator as two add or subtract accumulators to speed up calculation schemes. In addition, he described methods for instrumenting memory matrices capable of simultaneous interrogation for more than one stored bit.

T. H. BONN (Remington-Rand Div. of Sperry Rand Corp.) discussed the relative merits of core and transistor logic circuits. He claimed that at present delay was the only inferior characteristic of core circuits.

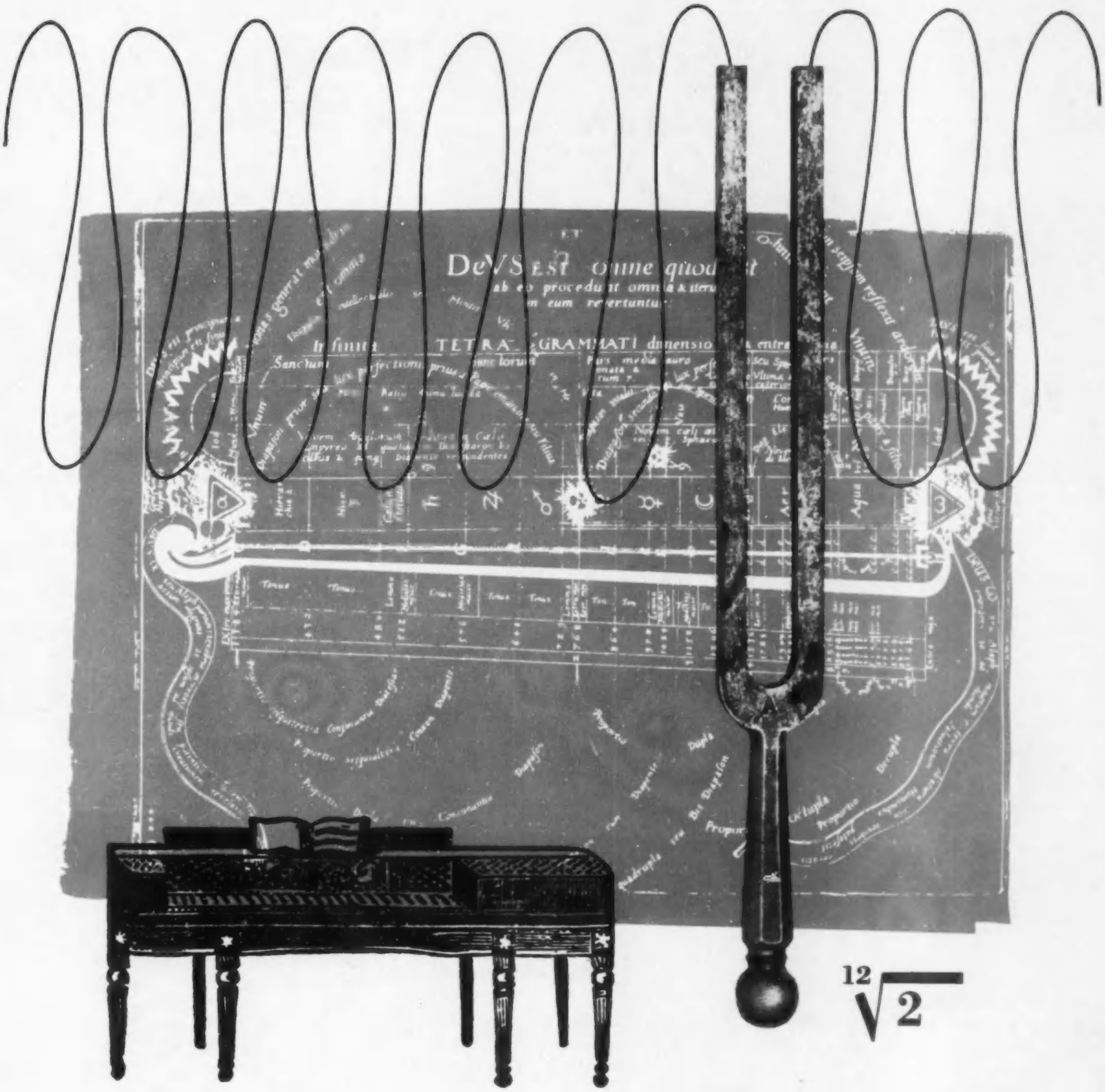
W. B. CAGLE (Bell Telephone Laboratories) reported that economic and efficient logic operations can be performed by mixed systems of diodes and transistors. Typical switching times: 30 to 70 millimicrosec.

DR. WAY DONG WOO (Datamatic Corp.) illustrated ramifications in his classic work in core shift registers. One interesting example was a two-dimensional shift register in which information can be advanced in either of two directions. Another was a reversible shift register.

B. DUNHAM (IBM) talking about the concept of multi-purpose logic devices, pointed out how the logic function of a unit can be modified as part of a program to increase flexibility in a computer.

HOLLAND'S A. VAN WIJNGAARDEN (Mathematical Center, Amsterdam) provided a scholarly survey of how potentialities of computer circuits built around memory units have been determined.

Robert W. Reichard


$\sqrt[12]{2}$

to appear, but they never arrived, although their papers were translated and read by Harvard staff members (an indication of the thorough planning and organization of the symposium).

First two days of the meeting were devoted mainly to theory, the last two days to components. A unique report on chemical switches was delivered by B. K. Green of The National Cash Register Co. According to Green, tiny droplets of light-sensitive fluid can be used to store information and give it up again in tiny fractions of a second. The phenomenon of "photochromism"* provides the two sable states required for switching action. Green also reported that an automatic process had been developed to produce many thousands of billions of these cells in a single batch operation. Three different colors of light can be used to read, write, and erase the information in these synthetic memory cells, so that the reading process does not destroy the information in the cells by changing their color.

Still another unusual paper on microwave logic was presented by W. D. Lewis of Bell Labs.

• **Duplication in the theory**—Some duplication in the theoretical papers was inevitable: Boolean algebra provides the general symbolism and graphs and charts assist the mind in visualizing and manipulating the expressed relationships. The uses of matrices were discussed by several speakers, and topology was introduced by J. P. Roth of IBM.

An unexpected development was presented by D. E. Muller, University of Illinois, in a paper entitled "A Theory of Asynchronous Circuits". Here vectors which represent the possible states indicate the rapidity with which the circuit elements settle down to their steady states. And these vectors form a mathematical lattice. The structure of this lattice is important in characterizing the behaviors of a circuit.

• **Russian claims**—The four Russian papers reflected the special interest in that country. The audience was reminded at least twice that "long before Shannon", a Russian had suggested these applications of Boolean algebra.

So much high-level data was dispensed in the four-day session that it

** When certain materials are exposed to lights of different colors, the material itself will change color. And this process can be reversed, providing two states.*


Accessories for Ferrac Amplifiers
400-CPS Phase-Sensitive Demodulator
FERRAC AMPLIFIER
M-943
DEMODULATOR TYPE D-5170
115 V, 400 CPS
26 V, 400 CPS
Your servo circuits are often simpler when they use DC lead and lag correction networks. Here is a magnetic demodulator that produces a polarity-reversible DC output from a 400-CPS phase-reversible control signal. The output can be mixed with other DC signals, and amplified in a Ferrac amplifier.
Type D-5170 demodulator has a stable null and is designed for use in zero-seeking systems such as synchro control transformers. Type D-5171 demodulator has a linear characteristic for use in proportional systems such as gyro pick-offs.
Both types operate under the same environmental conditions as do Ferrac amplifiers: −65 C to +85 C, 10 G vibration from 10 to 2000 CPS, and 30 G shock. Units are hermetically sealed for operation in any atmosphere.
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SUPPRESSION RHEOSTAT
EXPANSION RHEOSTAT
FERRAC AMPLIFIER
MAGMETER DETECTOR
MAGMETER INPUT
F-992
1000Ω
4000Ω
2 MFD
M-1057
FERRAC OUTPUT
115 V, 400 CPS
Magmeter Detectors
Where you require an output signal proportional to input frequency (or any parameter convertable to frequency such as RPM or pulse rate) you can use a Magmeter detector to advantage. This compact component delivers an output linearly proportional to input frequency within ±2%. The output can then be amplified or mixed with other control signals by a Ferrac amplifier.
Type F-992 Magmeter detector covers the band 375 CPS to 425 CPS. Other types are available covering any ±5% band (or wider) from 50 CPS to 5 KC or any band from 0 CPS to an upper limit that may be anywhere from 50 CPS to 5 KC.
MAGNETIC SERVO AMPLIFIER TYPE M-5178
Servo Power Amplifiers
750 Ω
M-943
M-5178
PHASE 1
PHASE 2
400 CPS 115 V
115 TO 150 V 400 CPS
Analog computer operations of your automatic controller are readily performed by Ferrac amplifiers. The resulting control signal can drive an Airpax servo amplifier to power a servo motor. These power amplifiers control the currents to both windings of split-phase motors. As a consequence, the stand-by power to the motor is less than with other types.
Type M-5178 servo power amplifier develops 6 watts output per phase. It is 1⅛ inches square, 3 inches seated height, has an octal pin base, and weighs 14 ounces. Other types deliver from 3 to 10 watts per phase.
FERRAC
Ferrac amplifiers are instrument type magnetic amplifiers of exceptional stability and linearity for use in guidance and automatic control equipments.
DESIGNERS
AIRPAX PRODUCTS COMPANY
ENGINEERS
ENGINEERING DIVISION • MIDDLE RIVER • MARYLAND

WHAT'S NEW

was hard for the human mind to grasp it all. Most of those in attendance are waiting eagerly for the proceedings to be published so that they may catch up on what they might have missed.

—Alston S. Householder

ISA National Nuclear Instrumentation Conference

ISA's first technical meeting on nuclear instruments, held in Atlanta in April, produced two significant developments: 1) formation of a nuclear division, and 2) a report presented for discussion by RP-25 Subcommittee on "Materials for Instruments in Radiation Service".

Under Chairman E. See Day Jr. of GE, the subcommittee has prepared recommendations for the selection of materials used in instruments in intense radiation. The preparation of such standards indicates the importance now being attached to the proper use of materials in instruments, particularly under unusual conditions of service.

RP-25 includes:

- A general guide for the selection of materials for use in radiation fields.
- Insulating materials—plastics and elastomers.
- Metals—properties of hardness, tensile strength, impact strength, fatigue strength, density and dimensional stability, magnetic susceptibility, and electrical resistivity.
- Special components, such as motors, thermocouples, ionization chambers, oils, and semiconductors.
- Shielding materials—desirable properties and a selection table.

The subcommittee is anxious to hear comments from ISA members on the new proposed recommended practices. Comments can be forwarded to Chairman E. See Day Jr., GE, 761 Building, Richland, Wash.

Attendance at the Atlanta meeting numbered about 250, slightly disappointing to ISA, which expected a turnout of 300.

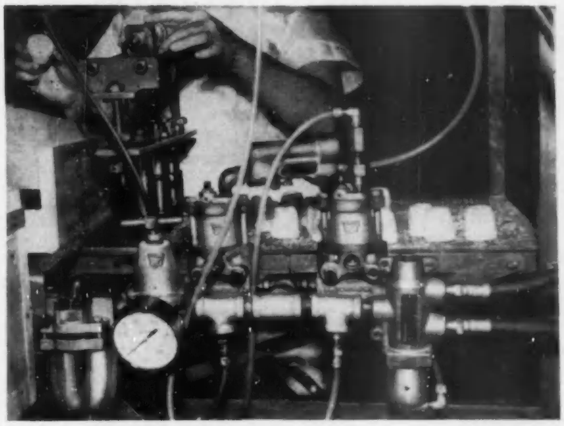
3rd ASME/IRD Conclave

Northwestern University in Evanston, Ill., was the scene of the third annual conference of the Instruments & Regulators Div. of ASME. Several AIChE delegates also attended this year. Subject matter of the meeting: application of frequency response techniques, analog computers, ran-

Progress in designing air systems:

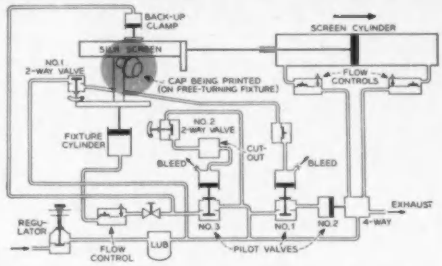
Here's an automating idea: Schrader Air Products in a precision programming operation

PROBLEM: To print bottle caps accurately at high speed.

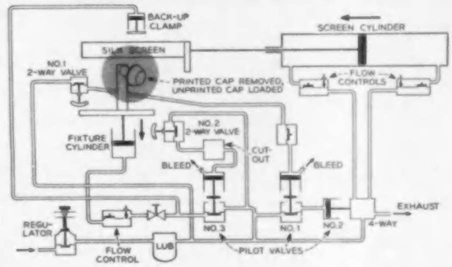


PROVED IN OPERATION: Prominent silk screen printer puts Schrader products to work at a profit.

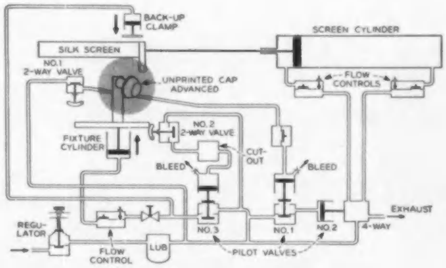
SOLUTION: Adapt Schrader Air Products to silk screen printer.



1 Fixture holding plastic cap on freely rotating fixture is held up against silk screen by Schrader cylinder. Another Schrader cylinder pushes screen sideways over the freely rotating cap, imparting the printed message.



2 Fixture with printed cap moves down, back-up clamp retracts and screen cylinder returns to initial position. Operator removes printed cap and loads another unimprinted cap.



3 Schrader cylinder advances fixture upward loaded with unimprinted plastic cap. Back-up clamp starts downward toward silk screen. And cycle starts all over again.

This is but one precision operation of the limitless operations which can be controlled *fast, economically* and *accurately* by Schrader Air Products. The hundreds of different units in Schrader's complete line can be employed alone or in combination to perform stamping, programming, forming, measuring, squeezing—other jobs too! And wherever air is used, economy is basic.

Test the performance of all your machines against the efficiency that could be achieved with air. Schrader engineering facilities are available to help you. Outline your problem to us and assistance will be prompt. Right now, mail the coupon.

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WHAT'S NEW

dom and impulse methods, and optimizing to the solution of actual control problems.

At previous IRD conferences, papers concentrated on theoretical and academic aspects of control theory. But this year the emphasis was on dollar and cents payout in using the "long hair" techniques. Among the highlights of the meeting was presentation of two technical papers ("Dynamic Field Tests of a Process Furnace" and "Dynamic Field Tests of a Steam Turbine") authored by P. R. Hoyt, B. D. Stanton, and D. C. Union of Shell Development Co. and presented by Union. Union pointed out that tests and subsequent improvements in controllability of the steam turbine saved about $75,000 per year at one installation.

The two papers sparked an active discussion—several listeners took issue with the interpretation of some test information and computed time constants of the process. But the audience was unanimous in commending Shell for taking the initiative in revealing so much actual experience in control.

Behind the scenes, the IRD executive committee met twice to consider such items as the automatic optimization program for its fourth annual conference at University of Delaware in April 1958; and Ted Belcher's (Minneapolis-Honeywell, Brown Instruments Div.) suggestion to establish an IRD committee on the subject of quantized data—its generation, handling and use in control.

—*H. R. K.*

CONTROL BITS

KS-54, Kollsman Cabin Pressure Control System, has been selected as standard equipment for the Fairchild F-27, new twin-turbo-prop passenger-cargo aircraft. System will monitor and control cabin pressure to assure passenger comfort during climbs.

Philco Corp. is building two completely transistorized TRANSAC S-2000 computers for delivery in 1958. The S-2000 is a large-scale electronic data-processing unit designed for on-line and off-line commercial, scientific, and military applications.

Lockheed Missile Systems Div. has set up a 12-hour course in computer programming to train employees to use its IBM 650 computer. Object: to ease work load on professional programmers. Only requirement for the course: knowledge of simple algebra.

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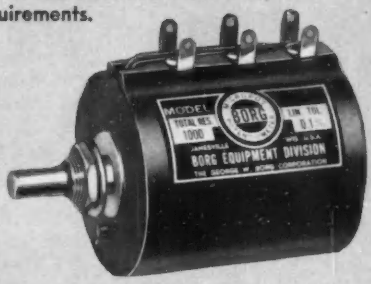
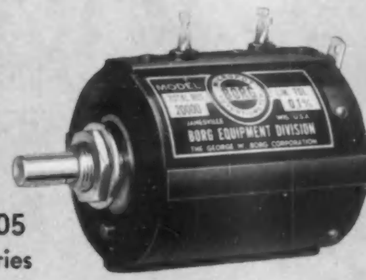
900 series

The new standard of high-precision potentiometers. Advantages include greater accuracy, finer resolution, lower torque, longer life and better performance under adverse environmental conditions. 48 standard models meet most special design requirements.



1100 series

Precision potentiometers that offer your products a price advantage in today's competitive markets. Engineered for easy installation with readily accessible terminals. Accurate, dependable, long lived.



205 series

Long a favorite for both military and commercial purposes. Has proved itself exceptionally rugged and dependable in years of use on many mobile and stationary applications.

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Your job is made easier when you use Borg Micropots. They're versatile . . . they're flexible. Standard models can be readily adapted to meet the special requirements of a wide variety of applications. What is more they have many exclusive advantages: — — absolute linearity, permanent accuracy, long life, and dependability. You can rely on them to meet your most rigid commercial and/or military specifications. They're readily available too. Production has been stepped up to assure prompt delivery of any model in any quantity. We invite consultation with your Borg "Tech-Rep". His helpful advice can often save you time and money. Write us today for his name and address. It will pay you to know him.

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The George W. Borg Corporation
Janesville, Wisconsin

ELECTRONIC – MECHANICAL BORG EQUIPMENT

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NACC Organized

Societies eye coordination of technical meetings in control systems field.

Technical societies are taking a look at ways to cooperate on and coordinate a mushrooming of activities in the control field. Authorized representatives of ASME, AIEE, IRE, ISA, and AIChE have formed a joint council of the American technical societies which conduct engineering and scientific activities in the broad field of control systems engineering. After naming the new group the North American Control Council, delegates framed two initial objectives:

1. Participation in the organization and operation of a proposed international federation of control systems engineering.
2. Coordination of the professional activities, meetings, conferences, symposia, and joint control meetings of American technical societies.

• **Chairman Oldenburger**—The delegates also elected a chairman of NACC: Rufus Oldenburger, professor of mechanical engineering at Purdue University and chairman of ASME/IRD. Oldenburger represented NACC when final plans were made in Dusseldorf, Germany, for the first formal meeting of the proposed international federation of control.

Although delegates took no formal steps at the first meeting to coordinate forthcoming meetings on control systems engineering, several of the delegates—who are doubling in brass as technical program chairmen for 1957 and '58 meetings—informally agreed on schedules and themes for these meetings:

▶ Professional Group on Automatic Control, IRE, "Nonlinear Control Theory and Practice" Aug. 19, 1957, at WESCON, San Francisco, Calif.

▶ Feedback Control Systems Committee of AIEE, "Computers in Control", Oct. 9-11, 1957, Atlantic City.

▶ ASME/IRD, "Automatic Optimizing", April 2-4, 1958, at University of Delaware.

Other officers of the new group: Harold E. Chestnut, General Electric Co. (AIEE), elected vice-chairman; William E. Vannah, editor, CONTROL ENGINEERING (ASME/IRD), elected secretary-treasurer.

There's one other dividend expected from NCAA: reduced meeting registration fees for members of participating societies.

Missile Pot Boils

Defense Dept. wrangles keep missile R&D policies in the air.

The long-smoldering dispute over the way missile research and development should be conducted—and with how much—is just one phase of the continuing controversy on U. S. arms buildup. But it is a major one.

Last January Secretary of Defense Charles E. Wilson examined the "second new look" in defense strategy, of which missile R&D is definitely a component, and said that "our basic military programs were generally valid . . . and would continue to be valid through the period of 1958-60." But Stuart Symington (D.-Mo.), reporting on his Senate Armed Services Committee's study of the military budget in February, didn't see it that way at all. And one of the results of the critical points he raised was an assignment of $700 million of last year's $900-million Air Force budget to development of long-range missiles.

• **Complex battle.** These, of course, are just two highlights in a running battle that is just as complex as some of the weapons around which it centers. But they will do as background for a third and much more recent development, one that, more than any other, seems to pull the strings tight on the bulging bag of arguments about missile research.

This, the resignation of Frank Newbury as assistant secretary of defense for research and engineering, has its greatest significance in the fact that Newbury was a powerful advocate of one way—the conservative way—of conducting missile R&D work. The 76-year-old retired vice-president of Westinghouse Electric Corp. had long been pushing a program to:

▶ Prevent military sponsorship of fundamental scientific research unless the project was clearly related to a specific military end-item—Newbury's view was that military funds should be limited to weapon development.

▶ Standardize weapon development as a means of curbing duplicate projects among the three military services and of holding back on volume production of a new item until all possible improvements could be phased into the preproduction model—the so-called "fly-before-you-buy" philosophy.

▶ Reorganize military R&D administration—with greater power for New-

bury's own Central Defense Dept. Coordinating Office to allocate funds and direct expenditures, at the expense of service contracting agencies.

Newbury's numerous critics in the military establishment and in industry argued that his "ultra-conservative" views "create an environment which stifles the growth of new ideas." The criticism became louder as these views were more and more reflected in official Defense Dept. decisions. One example: The hold-backs on the nuclear-powered aircraft and Northrop Snark missile projects. For the most part, the critics say that military-financed basic missile research must be increased, not restricted; and that missile R&D projects must be pushed into the hardware stage as fast as possible to reduce development lead-time.

• **Unexpected departure**—Newbury's resignation was unexpected; the Defense Dept.'s R&D office was put under his wing just a few months ago, when he was moved up from chief of applications engineering. Pentagon gossip is that his departure was hastened by pressure from long-time foe Donald A. Quarles, now deputy defense secretary and formerly assistant defense secretary for R&D and Air Force secretary, and from industry and academic members of the Pentagon's top-level Defense Science Board. The board, set up last year to provide overall guidance on long-range military research objectives, had objected to Newbury's increased authority.

It's tough to say what R&D policy changes are forthcoming. But most observers expect to see a liberalization of policy—with more money earmarked for basic research, more gambling to push development projects into production sooner, and less concern over standardizing development efforts.

MIT Inertial Guidance

Details of the MIT "inertial guidance system" for aircraft and missiles were disclosed in April. Charles S. Draper, head of MIT's Dept. of Aeronautical Engineering, explained that the system operates on the difference between inertial space (space unaccelerated relative to the fixed stars) and earth space (accelerated because of the rotation of the earth).

In the system are two important kinds of instruments: one measures a fixed direction while another measures directly "down". For the former,

WHAT'S NEW

MIT uses a specially designed hermetic integrating gyro, which spins at a rate of 12,000 rpm inside an inner cylinder known as a float (it actually floats in a heavy molasses-like fluid). The float pivots on sapphire bearings that are virtually frictionless. Three gyros indicate the three directions involved in navigation.

A Schuler-tuned pendulum, modified by MIT's Instrumentation Laboratory, is used to show the vertical that exists at any point. By measuring the angle between the vertical of a gyro and the vertical of the special pendulum, latitude and longitude can be determined. The inertial guidance system makes this computation continuously and automatically.

In 1953, MIT's system was installed on a B-29 and guided the ship from Boston to Los Angeles without any supervision from the pilot. The system's efficiency is said to have been improved since then.

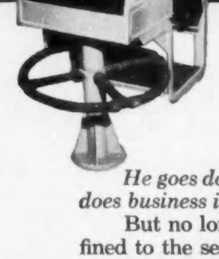
Instrument Men Study Medical Problems

Instrument designers and medical men will meet at a unique clinic this month to explore the potential of new instrument techniques for the medical profession and medical researchers. Co-sponsored by the Foundation for Instrumentation, Education, & Research—itself a new and unusual agency—and the New England Institute for Medical Research, the clinic will afford an opportunity for give and take between medical researchers and instrument designers. Instrument men representing a broad range of experience will attend the clinic.

For two days (June 10-11) the group will be closeted at NEIMR's laboratory at Ridgeway, Conn. First, medical researchers will brief the instrument men on some of the toughest medical problems in medical diagnosis and biology. They'll use physical and engineering terms that fit the designers' jargon. Then the instrument professionals will try to make suggestions for solving the problems.

Objective of the give and take: to produce outlines for two or three basic instrument research investigations to be conducted by means of grants made by the Foundation at qualified institutions.

If the so-called "conceptual clinic" turns out to be a success, the Foundation plans a series of them on various topics. Probably next on the list: the food industry.



AROUND THE BUSINESS LOOP

IBM Sells Most Complete 705 Since Consent Decree

The IBM 705 computer recently purchased by The American National Insurance Co. of Galveston, Tex., is not the first machine of its kind to be bought since IBM consented to put its automatic calculating machines on the market (CtE, March '56, p. 30), but it does have this claim to distinction: it has more peripheral equipment than any other machine acquired in this way, and so is the most expensive. Price is $1,364,750, very close to the figure of $1,649,800 which is advanced by IBM cost people for a complete hypothetical system.

It is interesting that one of the earlier purchasers of a 705 was Prudential Insurance Co. of America, another carrier, which bought only the barest essentials—these, according to IBM, consist of a console and automatic typewriter, $52,000; a central arithmetic unit, $613,600; and a power unit, $62,400. Assuming that both companies have similar paper-work problems, and that they brought in the 705's to help relieve these problems, one wonders why the discrepancy exists between the amount of equipment purchased. Biggest reason for Prudential's decision, it would appear, is the obsolescence factor; for American National's, perhaps the idea that new machinery will not do much better in whittling down more or less straightforward papers logjams than the equipment in operation today.

Awaiting the 705 at American National are such chores as these: register preparation and debit accounting for industrial policies; issue, premium and commission accounting, loan accounting, and notice billing for ordinary policies, and reserve valuations, actuarial studies, and general accounting operations.

Also of interest is what IBM says about its own net income for the first three months of 1957, for this period rounded out the first year in which the company sold as well as leased its equipment. Most significant figure in this respect is $1,002,334, the amount of money earned after taxes on outright sales "to customers of machines previously under lease to them" (some purchase orders from nonrenting customers are on the books, but so far no sales of this sort have been consummated). This $1-million-plus figure, incidentally, helped to boost the first-quarter net income (after Federal taxes) to $18,745,607, an increase over the like period of 1956 of $3,757,282.

Another IBM unit, the 704, is the core of a new computing center being built in Linden, N. J., by Esso Research & Engineering Co. This machine, however, as far as can be determined, has been leased and not purchased. Still, it does have this unique quality: it is only one of two in use throughout the oil industry. Esso's sights have been set on 30 employees for the center by 1958, and on a permanent location in Floral Park, N. J., by 1960.

(For news of another IBM installation, see story below on Datics Corp.)

Burroughs Share in SAGE: More Than $23 Million a Year

Within less than a year more than $23 million in Federal funds has been funneled into Burroughs Corp. for work on the SAGE system of continental air defense. Latest SAGE contract assigned to the Detroit firm totals $1,828,149 and calls for electronic data processing and transmitting equipment. The plus-$23-million figure represents $17 million for equipment and spare parts, and $7 million for installation and maintenance.

Fenwal and Graviner, Ltd., to Trade Patents, Knowhow

An agreement involving a wholesale cross-licensing of patents between Fenwal, Inc., and Graviner Mfg. Co., Ltd., of England, will make it much easier for aircraft manufacturers on both sides of the Atlantic to obtain air-safety devices for their products. Not just patents, but technical and manufacturing information, too, are covered by the agreement, which sets up what both companies consider to be the basis for a unique international standardization of materials and services.

Most immediate result will be a domestic source of Fenwal equipment for British and other airlines operating American-built planes, and a similar source of Graviner equipment for those U. S. and Canadian airlines that use the Viscount and other British designs. Handsome amounts of R&D data collected by Fenwal and Graviner

teams doing applied research in the field of temperature technology will be furnished to the exchange training programs contemplated by both companies. Among the devices scheduled for "trade" are Fenwal thermostats, overheat detectors, jet-engine thermocouples and harnesses, and thermistor-actuated temperature controllers, and Graviner fire-detection systems, automatic high-rate discharge bottles, inertia and crash switches, and explosion-protection equipment.

Texas' New Datics Co. Growing by Leaps and Bounds

Datics Corp., now in operation in Fort Worth and Dallas, Tex., bills itself as "the first completely integrated data processing, computing and data reduction service firm in existence". Incorporated a year ago but only recently under full steam (an open house for the press was held just last March), Datics already claims big companies among its clients. For one of these, Burroughs Corp., the Texas company, which also designs specialized equipment, has built a console for systems controlled by a Datatron computer. Other Datics jobs in the works: electrical load calculations, water networks calculation by the Hardy Cross method, flash vaporization of hydrocarbons, oscillograph reading with automatic punching of digitalized data, internal accounting.

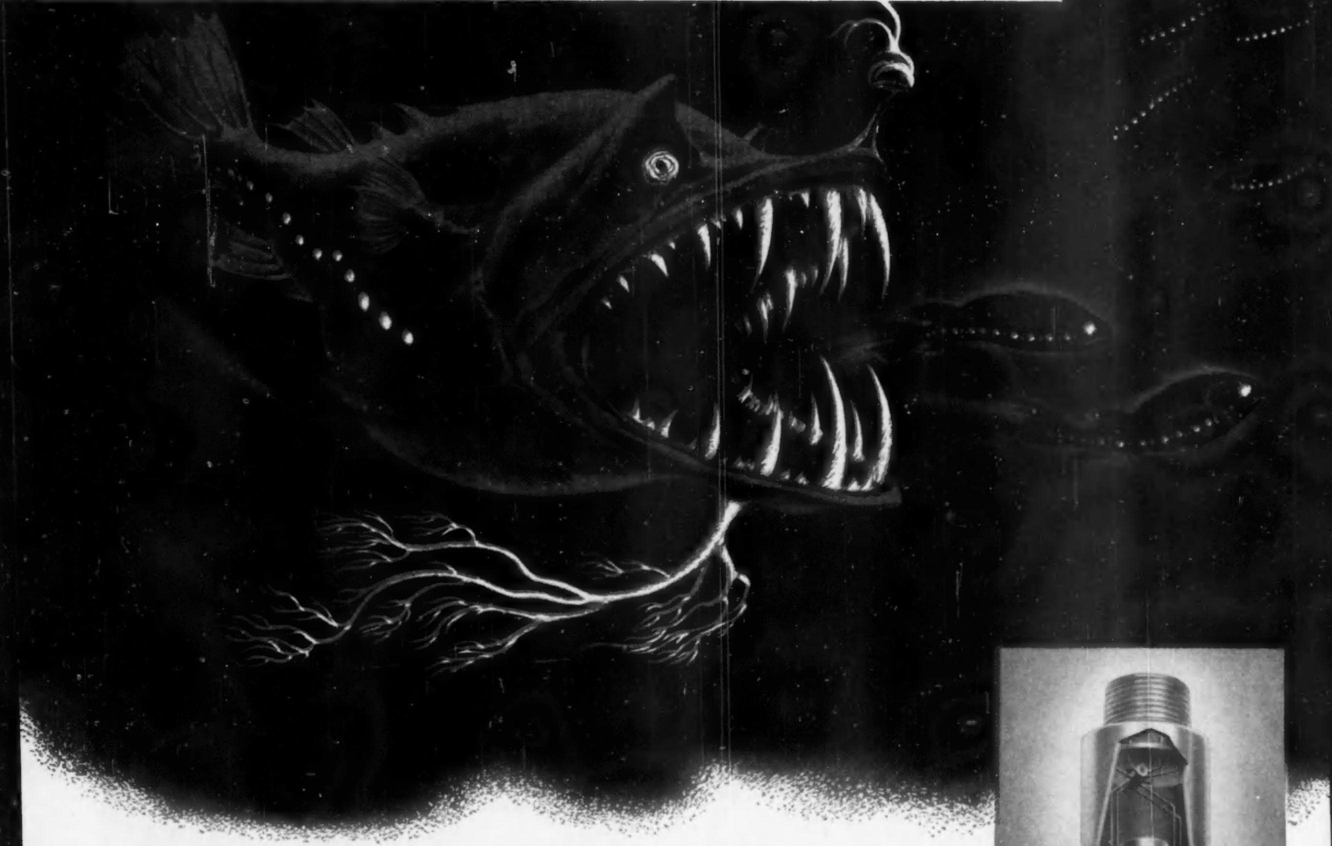
In April, when Datics expanded into Dallas, an IBM 705 computer came along, too. IBM's H. C. Wendler, manager at Dallas, was as enthusiastic as the Datics people themselves. "This contract," he said, "represents the largest order for an electronic computer of this type received by IBM in this area. By this action, Datics will establish the Dallas-Fort Worth area as the computer and data processing service center of the Southwest."

Up to that time, Datics had been doing business at Fort Worth with a medium-sized magnetic drum computer and two semi-automatic data-reduction systems. The move to Dallas, Datics' President Kenneth L. Austin said, was made much sooner than had been expected.

President Austin has been working with computers since he finished graduate work at the University of Oklahoma and UCLA. His first job was with Douglas Aircraft Co., where he was in charge of the Digital Computer Laboratory. Then came a stretch

(*Continued on page* 198)

This old codger safely gages pressure by instinct . . . BUT

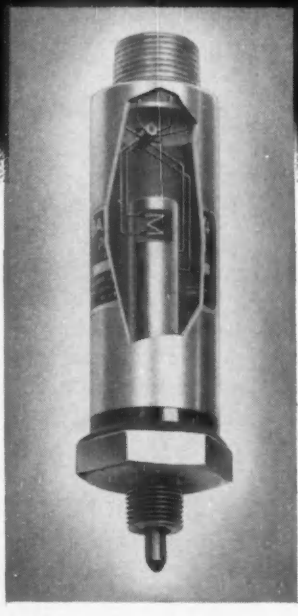


You can rely on SR-4® Pressure Cells to measure and control all <u>industrial</u> pressures safely to within ±¼% accuracy

The life of this toothy specimen depends on his staying at extreme ocean depths under many tons of pressure. If he ventures up too high—blooey! Suddenly diminished pressure causes him to literally explode.

B-L-H Fluid Pressure Cells are *the one way* to measure absolute or differential pressures with consistent accuracy to within ±¼%. They convert pressure changes directly into electrical changes—no moving parts to wear out, no long pressure lines with possible leakage and fire hazards. The signal can be fed to Baldwin indicators, recorders, controllers or data processing instruments—for our fishy friend, it could even activate a servomotor that would angle his fins downward and take him out of danger.

Whatever your pressure measurement problem, a B-L-H representative will be happy to help you, from selecting the proper transducer to engineering a complete pressure measuring system. Remember, a system is only as accurate as the transducer. Write today for your free copy of Bulletin 4306 on rugged, compact, reliable SR-4 Fluid Pressure Cells.



SR-4 Fluid Pressure Cells, using SR-4 Bonded Wire Strain Gages, are rugged, dependable and convenient. Typical cells show no loss of accuracy after 1,000,000 cycles of pressure at 100% of capacity. A wide range of SR-4 Pressure Cells is available for any industrial application.

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THERMISTOR DEVICES GIVE 1 TO 100 POINT TEMPERATURE CONTROL

Fenwal Units' Accuracy is .25% of Scale

ASHLAND, MASS. — Fenwal engineers here have designed a new Controller using a thermistor and a simple electronic circuit, and the result is a temperature-control system versatile and accurate to within .25% of scale.

The thermistor principle is this: the electrical resistance of the sensing element decreases as its temperature rises. The resistance changes for very small temperature changes are large, making extremely accurate temperature measurement possible.

In the Fenwal system, the thermistor, with its amazing sensitivity and fast responses, feeds an electronic bridge circuit that uses standard tubes. The small thermistor probe, available in several styles, is mounted at the point you wish controlled.

You can mount the compact Unit Controller up to 200 feet away from the control point without losing sensitivity. You can connect it with ordinary lamp cord.

Tailor-Made Designs

But possibly the biggest news in the design is the way the Unit Controllers can be assembled with a common power supply, like building blocks, to provide you with a central system serving up to 100 control points.

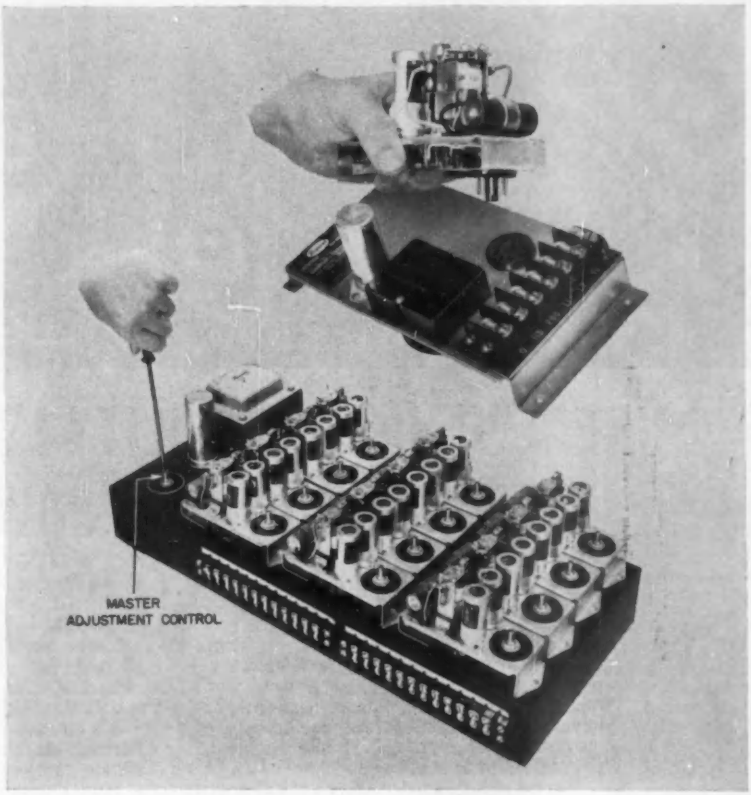
The units are, of course, ideal for use singly as well — each unit serving a single control point, each unit with its own power supply.

The many possible combinations of units are known collectively as the Fenwal Series 53000. There are four standard temperature ranges for you to choose from: −100°F to 50°F; 0°F to 150°F; 100°F to 300°F; and 200°F to 600°F. Special ranges can, of course, be supplied in most cases.

Each Controller includes a potentiometer for temperature adjustment, which you can locate remotely, if you wish. For multiple units, you can have a single master control. This control will let you adjust a complete system, while permitting compensating adjustment for each individual Controller, too.

These Thermistor Controllers are already serving hundreds of companies in many industries. Why not yours? You'll be surprised how inexpensive good control can be.

Designers and process engineers — you will want to have details on this new advance in precision temperature control at your fingertips. Write for information on the Series 53000 Unit Thermistor Controllers to **Fenwal Incorporated, 596 Pleasant Street, Ashland, Mass.**



FENWAL'S SERIES 53000 UNIT THERMISTOR CONTROLLER — Serves a single temperature control point, but can be combined easily with others, like building blocks, to make up a central system serving up to 100 control points with a single master control if desired. You should know about this. Write Fenwal for details.

Fenwal

CONTROLS TEMPERATURE
. . . PRECISELY

Industry-wide acceptance of super-durable E-I hermetically sealed terminals has made necessary further expansion of production facilities. The new plant in Murray Hill, New Jersey is one of the most modern in the electronics industry. New equipment, improved processes and larger capacity will make it possible to expand customer service on standard E-I terminals and custom seals.

Other E-I facilities will continue to serve the industry at Irvington-On-Hudson, New York. Complete research laboratory where technicians are constantly at work anticipating future design problems.

NOW–a new and expanded plant...

for the Pioneer Producer of

COMPRESSION SEALS*

Specify E-I for performance *plus* in commercial and military service:

Compression Seals	Threaded Seals
Multiple Headers	Transistor Closures
Sealed Terminals	Miniature Closures
Condenser End Seals	Color Coded Terminals

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MURRAY HILL, NEW JERSEY

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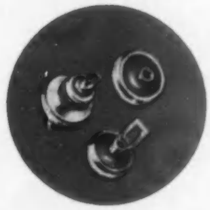
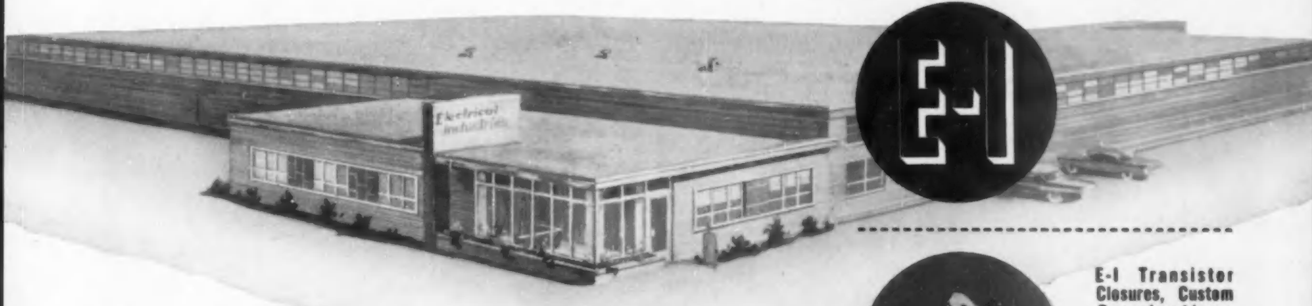
E-I Single Lead Terminals and Multiple Headers
Super rugged, compression terminals available in standard types to meet practically any requirement. Custom designs to specifications.

E-I Hermetically Sealed Plug-in Connecters
Keyed and gaged for use with RETMA octal type sockets. Available for vibrator, chopper, lock-in and noval sockets.



E-I End Seals for Tubular Closures
Completely strain-free. Afford a permanent hermetical seal for condensers, resistors and other tubular-type components.



E-I Transistor Closures, Custom Terminations
For transistors and other components requiring hermetic sealing. Available complete with closures or customer's parts sealed if required.

*Canadian Pat. 523,390; British Pat. 734,583
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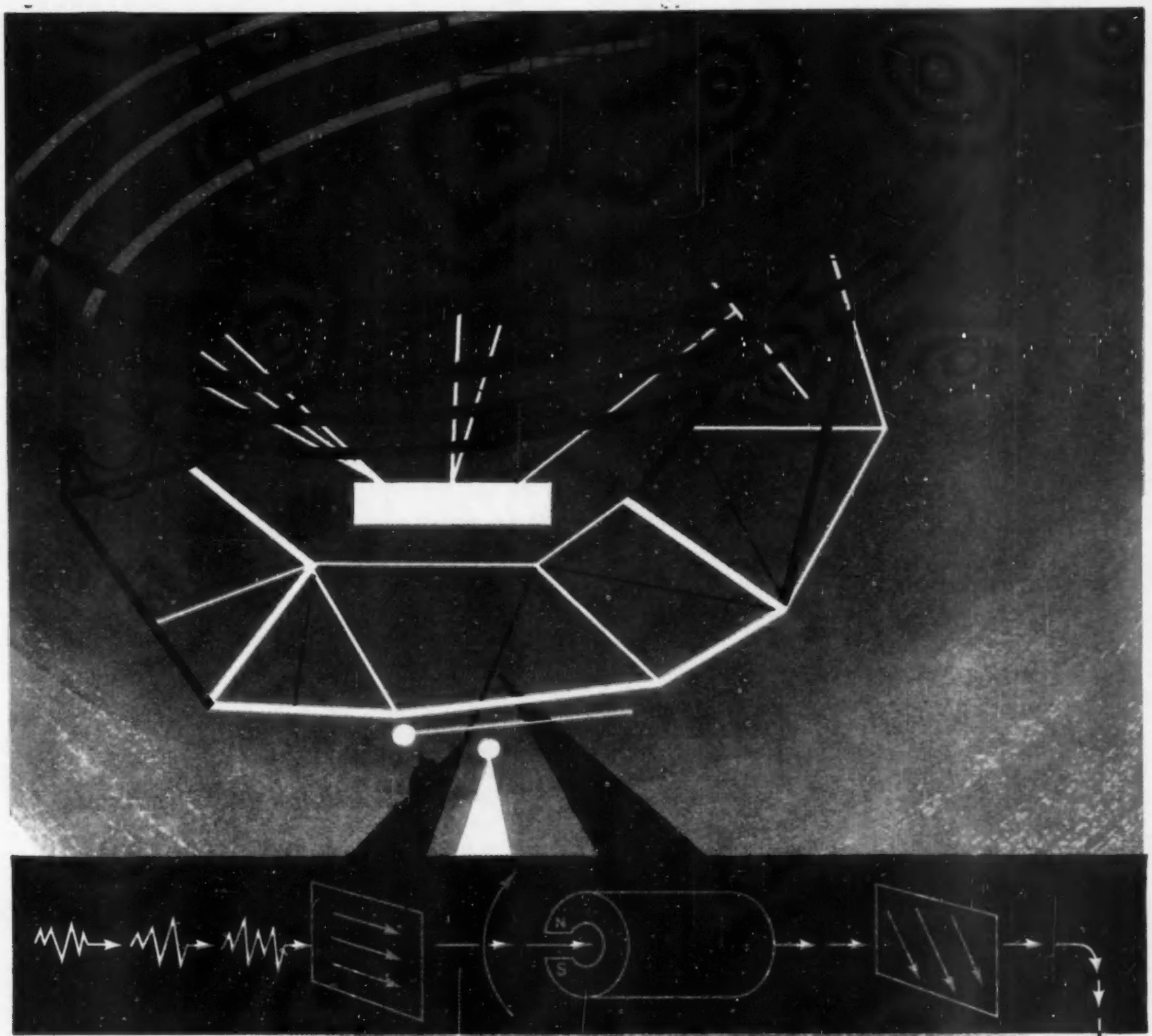
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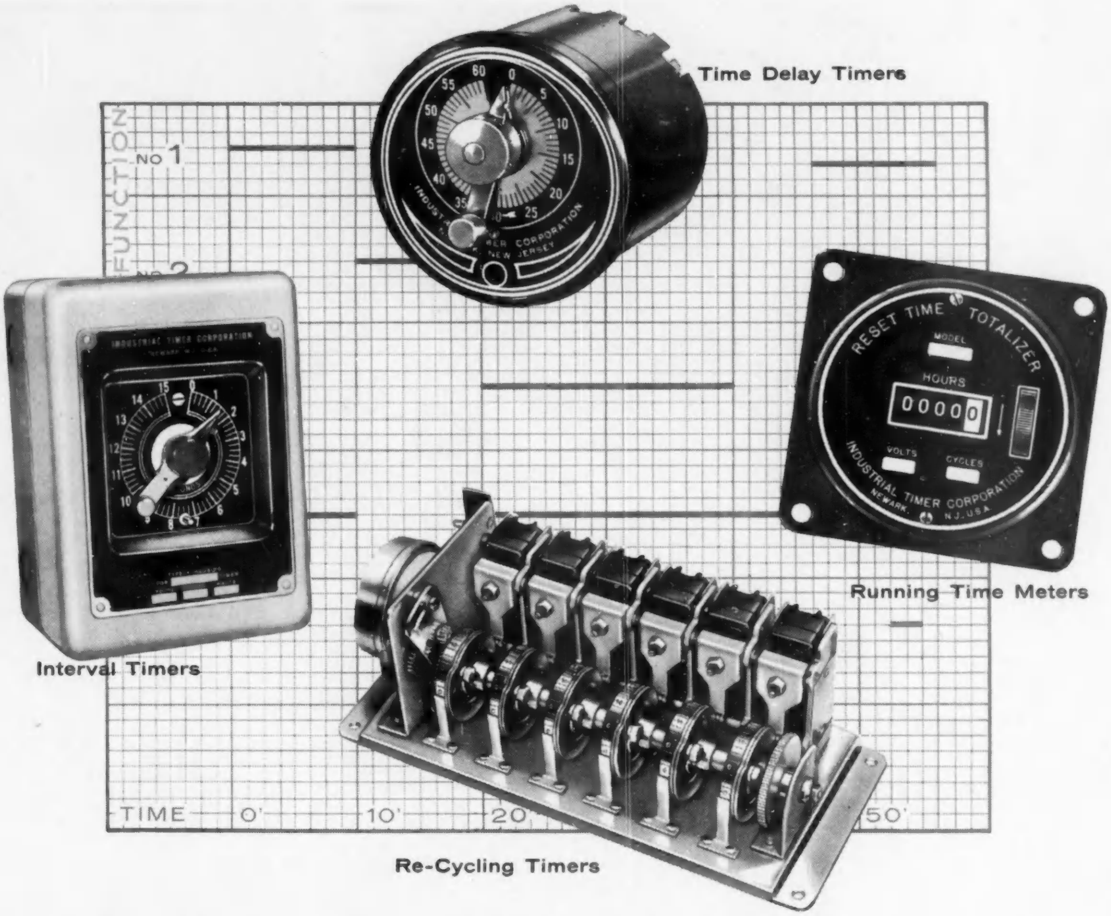

Timers for Automatic Control ...Standard or Special?

You'll get quick deliveries from Industrial Timer

If slow deliveries of timers have been delaying you in your automatic control projects, try us! True, your problem may be different and difficult indeed, for no two automatic control jobs are exactly alike. But our record in helping out in situations like these is excellent. For in this field we have a valuable background, twenty years of timer experience to be exact, that has provided us with the special knowledge required to supply our customers with the right answers.

How do we do it? The answer is in what we believe to be the largest variety of standard and combination timer units anywhere in the industry. To fill the widely varying needs of our customers, we manufacture a complete line of timers in the four broad classifications illustrated above: Time Delay Timers, Re-Cycling Timers, Interval Timers, and Running Time Meters. From these our timer engineers have developed 20 basic types which they have so far combined in over 1000 different ways. Therefore—many jobs that would seem to require a special timer, are in fact, a standard timer with us.

And our large stock assures you of rapid deliveries—even when we have to create a brand new timer for your special needs. So why not send us your specifications. You'll get a prompt reply and you may save yourself much lost motion.

Timers that Control the Pulse Beat of Industry

INDUSTRIAL TIMER CORPORATION
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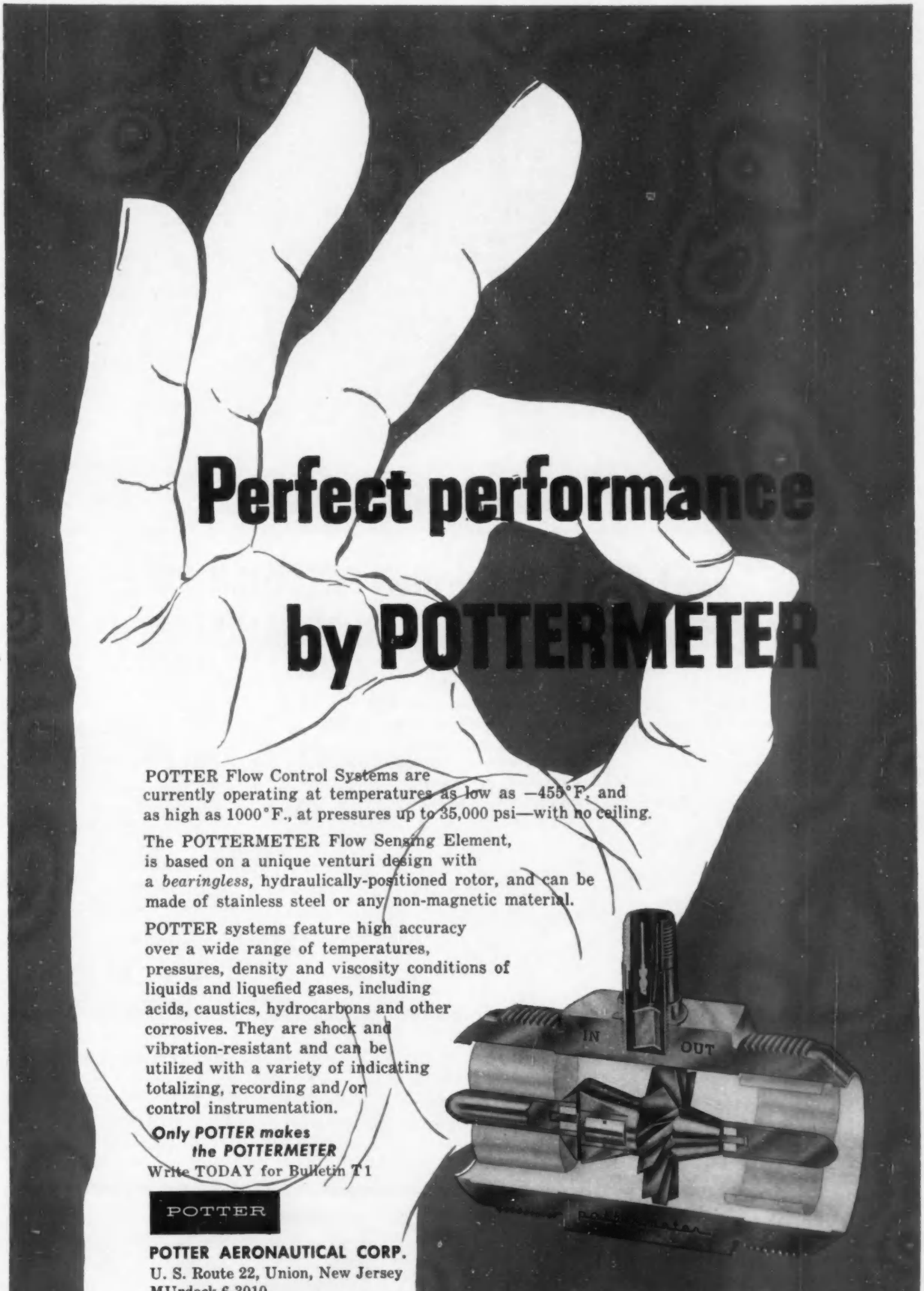
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POTTER Flow Control Systems are currently operating at temperatures as low as −455°F. and as high as 1000°F., at pressures up to 35,000 psi—with no ceiling.
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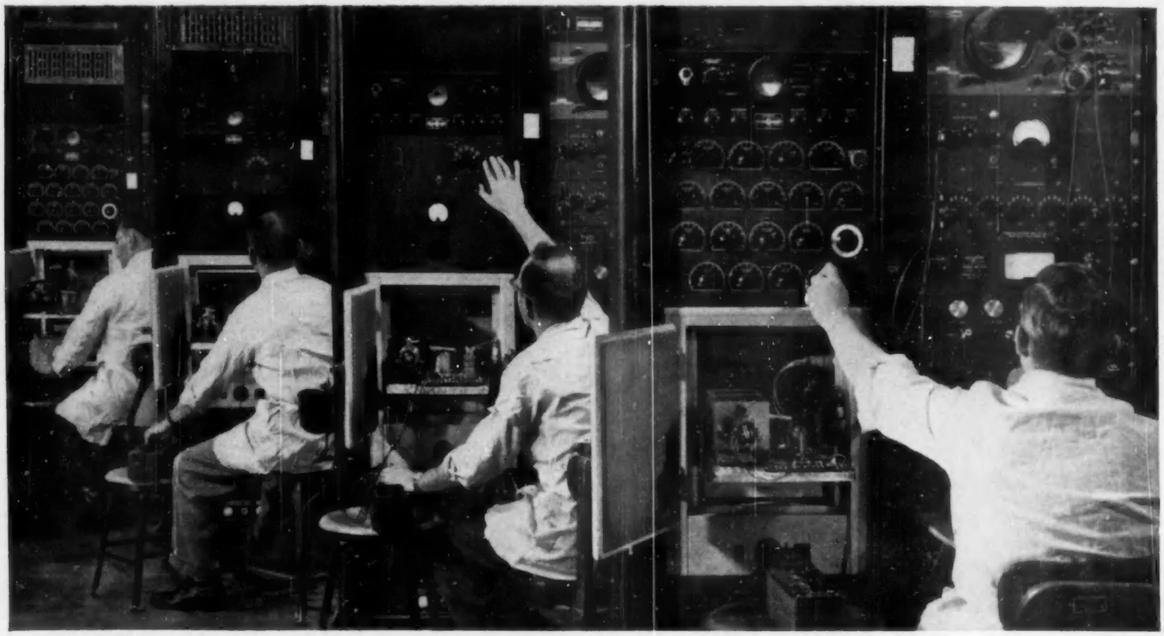

Bendix-built production test equipment calibrates precision induction rate generators and temperature compensating networks as a team.

GET FAST DELIVERY ON HIGH PRECISION RATE GENERATORS AT BENDIX "SUPERMARKET"

You're used to fast delivery at minimum cost from the Bendix Synchro "Supermarket", but maybe you don't know that this applies to such specialized, high-precision equipment.

The photo above shows the extensive production facility used to test Bendix induction rate generators and temperature-compensating networks as a matched pair. It's your assurance that precision rate generators you buy from Bendix will have the accuracy of laboratory-built instruments. Yet we produce them at almost assembly-line speed.

Extensive calibration enables us to promise generator accuracy within .15 of 1 per cent up to 3,600 rpm, unmatched in a production model such as this. Actually, at 4 volts and 3,000 rpm—the range at which the instrument will more commonly operate—linear accuracy is even greater: within .05 of 1 per cent.

District Offices: Burbank and San Carlos, Calif.; Dayton, Ohio; Seattle, Wash.
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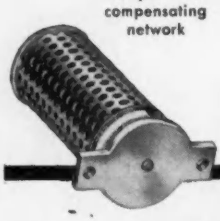
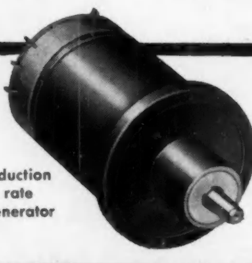
Temperature-compensating network





Induction rate generator

AVERAGE ELECTRICAL CHARACTERISTICS

Rated excitation	115 volts, 400 cycles
Output voltage gradient	2 volts per 1000 rpm
Output voltage	6 volts ± 0.05% at 3000 rpm
Phase shift	0 ± 0.1 degrees

AVERAGE MECHANICAL CHARACTERISTICS

Rotor moment of inertia	0.57 oz.-in.^{2}
Operating temperature range	15°C. to 75°C.
Weight:	
Rate generator	1¾ pounds
Compensating network	¼ pound

Eclipse-Pioneer Division
TETERBORO, N. J.

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AVIATION CORPORATION

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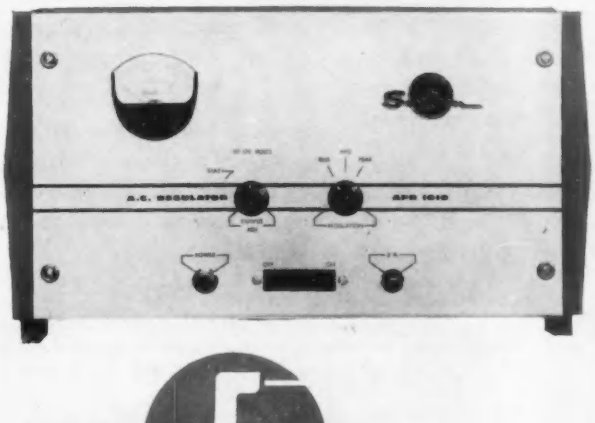
- ***FIVE* PRINCIPAL SENSING ARRANGEMENTS**

1. INTERNAL 2. EXTERNAL 3. REMOTE 4. CONSTANT CURRENT 5. DC

ELECTRICAL CHARACTERISTICS:

Input	95-130 VAC, 1ϕ (50 or 60 cps ±10%)
Output	115 VAC, adj. 110-120V
Regulation accuracy (RMS, average, or peak, switch selected)	±0.1% against line ±0.1% against load
Distortion	3% max.
Load	0-1000VA
P.F. range	Unity to 0.7 lagging
Recovery time	0.1 sec.

Write for complete technical data.



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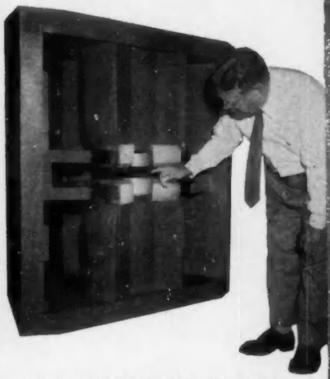

MASS SPECTROMETER SEPARATES ELECTRON PARTICLES

This mass spectrometer for basic research in the petroleum industry required an extremely stable, high-intensity field which could be varied.

This assembly, which incorporates a massive 1,300-pound Indiana Alnico permanent magnet, provided the answer. It has a maximum field strength of 6,000 gauss, and stability is maintained without the use of complex control equipment normally associated with electromagnets.

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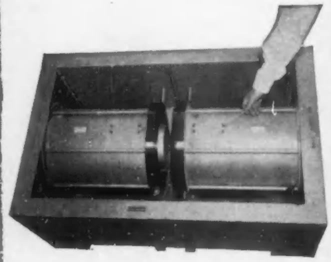
This electronic computer manufacturer required a permanent magnet housing for the magnetic tape reader and recorder unit of the processing machine in order to improve sensitivity.

Using Alnico for this housing brought on immediate improvement in signal strength . . . and better sensitivity because of the magnet's high efficiency.



NUCLEAR RESONANCE RESEARCH UNIT USES 1,000-LB. MAGNET

The University of Chicago, renown in the field of basic research, required a high intensity magnetic field to extend their research in nuclear resonance.

This huge permanent magnet assembly, containing over 1,000 pounds of Indiana Alnico, produces a field of 6,750 gauss. The stability — an inherent quality of permanent magnets — is maintained without the use of costly controls.

How three unusual products use Alnico permanent magnets plus creative design ... by Indiana

These dramatic examples of the use of Alnico permanent magnets illustrate how the creative engineering and manufacturing skill of The Indiana Steel Products Company have combined to meet the critical requirements of three unusual products.

This same experience can be put to work for you, too . . . regardless of application. Indiana offers the largest staff of magnet engineers and the most complete research and production facilities in the world to assist in the development of permanent magnets for use in your products.

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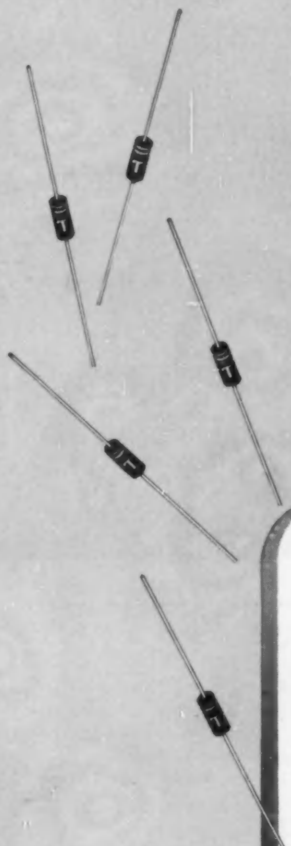
Transitron

Fast Switching
SILICON DIODES



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- High voltage ratings
- Operation to 150° C

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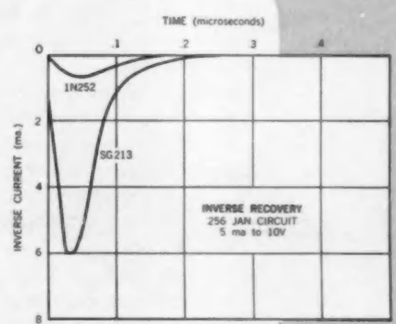
SG228	100	.25 @ 175V	200	1
SG226	100	.25 @ 60V	80	1
SG223	30	.25 @ 175V	200	.5
SG221	30	.25 @ 60V	80	.5
SG213	5	.25 @ 175V	200	.3
SG211	5	.25 @ 60V	80	.3
Low Capacitance Types				
1N251	5 @ 1V	.1 @ 10V	30	.15
1N252	10 @ 1V	.1 @ 5V	20	.15

Measured in the 256 – JAN Recovery Circuit



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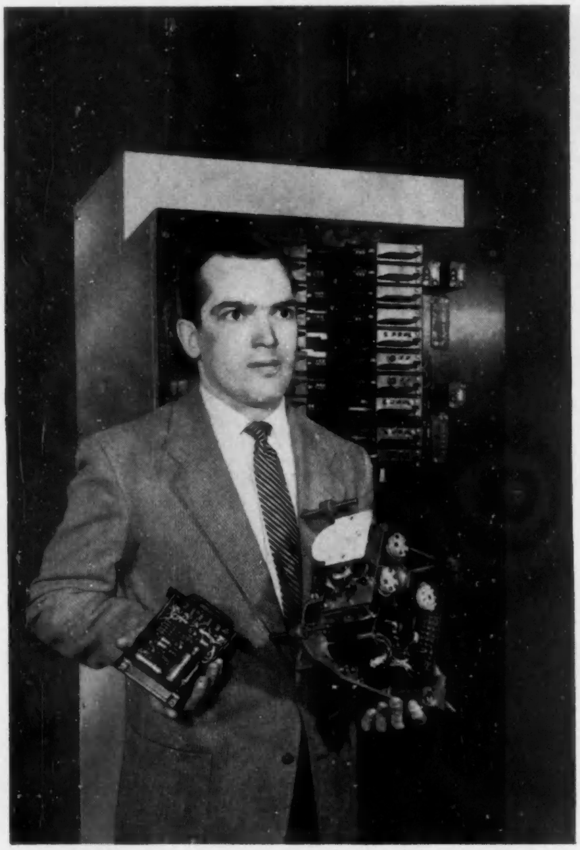
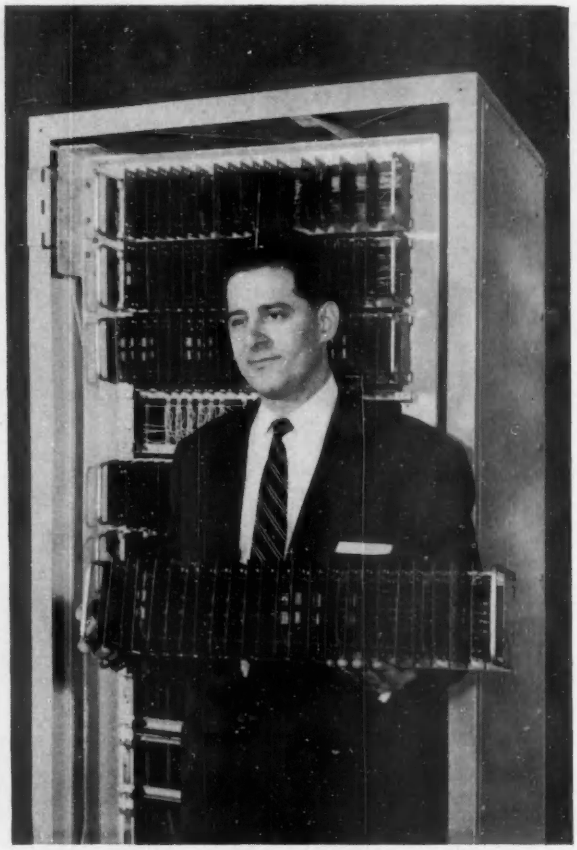


Robert Rossler, FICo engineer, holding plug-in analog modules — a transistorized amplifier unit and an electro-mechanical unit. Electronic panel of analog computer is in background.



FICo digital engineer Peter Carbone holding digital module, comprised of easily removable transistorized printed circuits. Rack-type digital computer is in background.

ANALOG or DIGITAL:

WHICH TYPE OF SPECIAL-PURPOSE COMPUTER IS BETTER?

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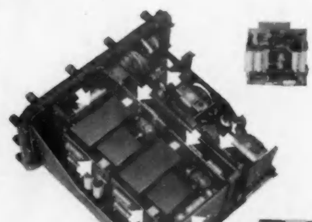
FICo has developed and produced special-purpose computers to handle an extreme variety of problems — including missile and rocket launching, missile guidance, airborne and tank navigation, test and other data processing, degaussing, torpedo launching, gunfire control, and many others.

FICo modular techniques as applied to an amplifier for an airborne navigational system. Arrows point to printed circuit amplifiers. Two typical cards are shown at right.



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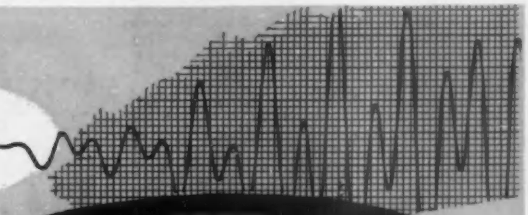

TECHNIQUES and DEVELOPMENTS in oscillographic recording

FROM SANBORN

RECORDING METHOD USED IN SANBORN DIRECT WRITERS, AND A REVIEW OF THEORETICAL AND ACTUAL ERROR FACTORS

Figure 1 shows the basic scheme by which Sanborn oscillographic recording galvanometers produce graphic records of electrical signal values. If the rapid deflection action of the heated ribbon tip stylus is visualized when current flows in the coil, it can be seen that a straight line at right angles to the chart length is recorded on the chart, at the point where the chart is drawn over a knife edge. The trace, therefore, is a true rectangular co-ordinate graph.

Since this is essentially a process of expressing coil (or stylus) deflection *angles* in terms of *distances* on a chart, the trigonometry of the situation (Fig. 2) must be examined to ascertain the accuracy of the method. Initially, and when θ is small, the tangent and the angle are almost equal numerically. The expression $D = R \tan \theta$ can, therefore, be rewritten $D = R\theta$ (approx.). To the extent this latter expression is true, deflection distances (rather than deflection angles) are an accurate measure of signal values. But to determine the extent of error resulting from using this approximation, the following data have been calculated*, using a chart width of 25 mm either side of zero ("D" in Fig. 2) and effective stylus length of 100 mm ("R" in Fig. 2) in the series expansion for the tangent function. Error as a function of deflection then becomes:

FIG. 2

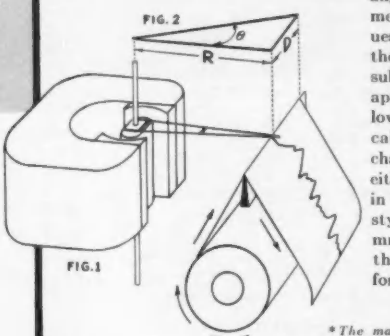

FIG. 1

D mms	Radians	Theoretical Error ϵ	Corrected Error δ	Corrected Error in mms
10	.10	.0033	0	0
15	.15	.0075	.004	.06
20	.20	.0133	.010	.20
25	.25	.0209	.018	.45

When the recording system is calibrated, that calibration is often made on the basis of a one centimeter deflection from the chart center, or by means of a two centimeter deflection starting one centimeter below chart center and finishing one centimeter above chart center. In either case the deflection at one centimeter from chart center is accepted as the standard, and, therefore, is without error. The foregoing table can therefore be corrected by subtracting .0033 from each of the error terms to show the error, δ, to be expected in actual use. The final column in the table shows this error in mms.

Since the active length of the stylus increases as θ increases, deflection D increases more rapidly than θ. All positive error terms in the series expansion bear this out, but the error terms would occur as predicted only if the galvanometer produced deflections exactly proportional to coil currents (that is, ideal spring properties in the torsion rods and uniformity of magnetic field). Pole tips in Sanborn galvanometers are proportioned so that in maximum deflections, galvanometer sensitivity *decreases* slightly, the compensation resulting in *actual* linearity better than that predicted in the table.

** The mathematics involved here, as well as a discussion of fixed length stylii, design parameters affecting over-all galvanometer performance, etc., are contained in an article by Dr. Arthur Miller "Sanborn Recording Galvanometers", published in the May 1956 Sanborn RIGHT ANGLE. Copies are available on request.*

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low noise level

excellent stability

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rugged construction

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It can be used to convert a low level d-c signal (such as 10 microvolts produced by thermocouples and photocells) into a low level a-c signal, which can be further amplified to operate various kinds of control apparatus in null balance servo systems, industrial instruments, and other automatic controls.

The Microverter may also be used as a synchronous rectifier to convert low level a-c signals to d-c without loss. An important new field of application is chopper-stabilized operational amplifiers where minimum amplifier drift is important.

Low noise level of the Microverter is due to: (1) Extremely low driving power required — 2-volt coil will operate at 4 milliamperes (approximately 4 milliwatts); (2) load circuit members isolated from the magnetic field of driving coil; (3) contacts thermodynamically symmetrical to eliminate stray thermal emfs.

This new hermetically sealed chopper features excellent stability under shock and vibration, long operating life, rugged construction. *10,000 hours' service life has been achieved* at contact load of 1 ma at 1 volt d-c, resistive.

SPECIFICATIONS OF A TYPICAL MICROVERTER	
MODEL NYZA 6192	
d-c coil resistance	215 ohms
Drive voltage	2 volts
Drive frequency	60 cycles per second
Dwell time	45 plus or minus 3 percent
Balance	Within 2 percent average; 6 percent maximum
Phase angle (nominal)	74 degrees at 60 cps
Contact rating	2 volts at 2 milliamperes resistive load
Contact noise	10 microvolts maximum when operated into 1000 ohm resistive load
Ambient temperature range	30° F. to 130° F.

HELPFUL NEW DATA SHEET

Includes Barber-Colman Microverter description, specifications, and schematic diagrams for typical applications. Write today for your free copy or contact the nearest Barber-Colman engineering sales office: Baltimore, Boston, Chicago, Cleveland, Dayton, Fort Worth, Los Angeles, Montreal, New York, Philadelphia, St. Louis, Seattle.

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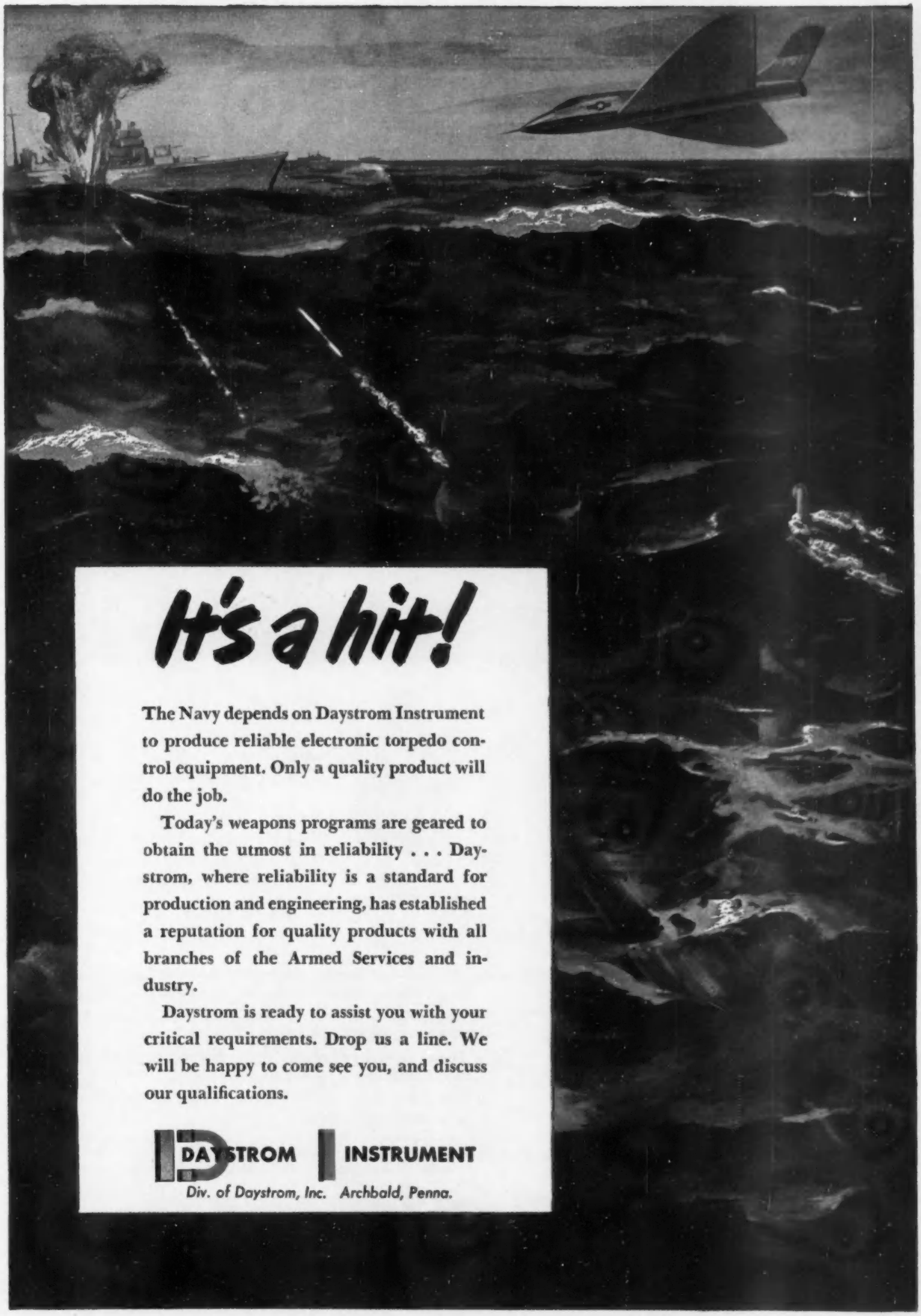
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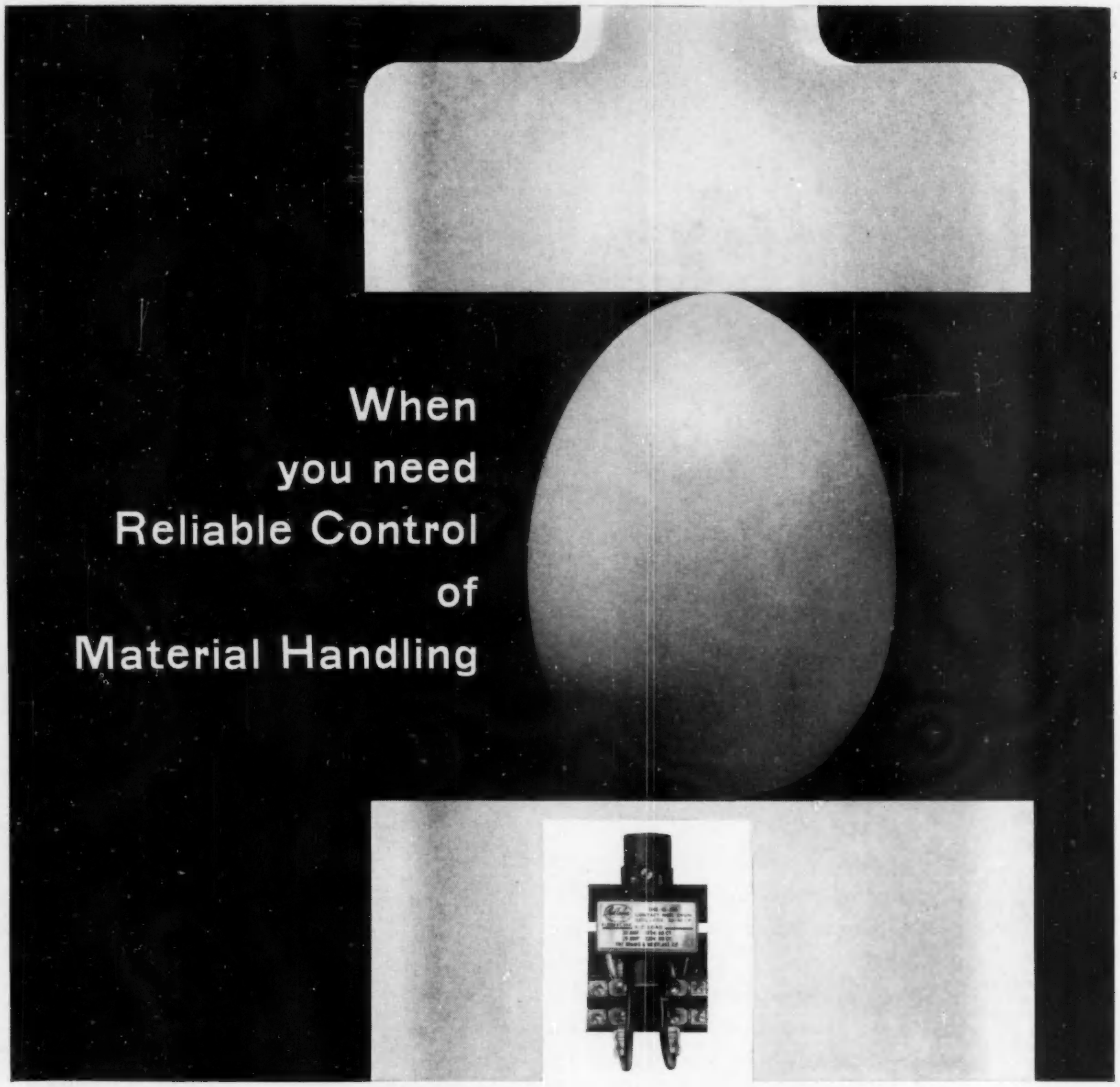

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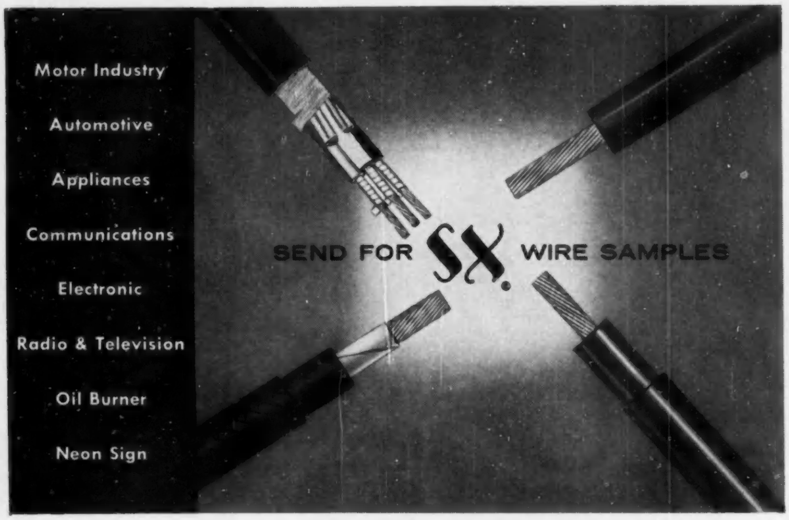

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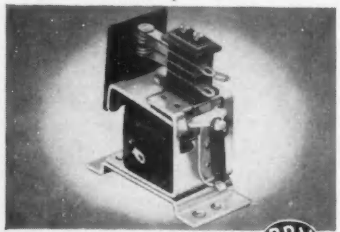

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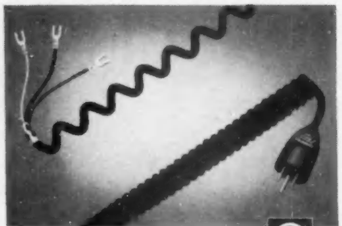

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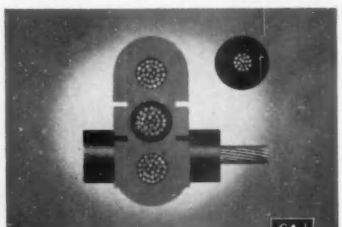

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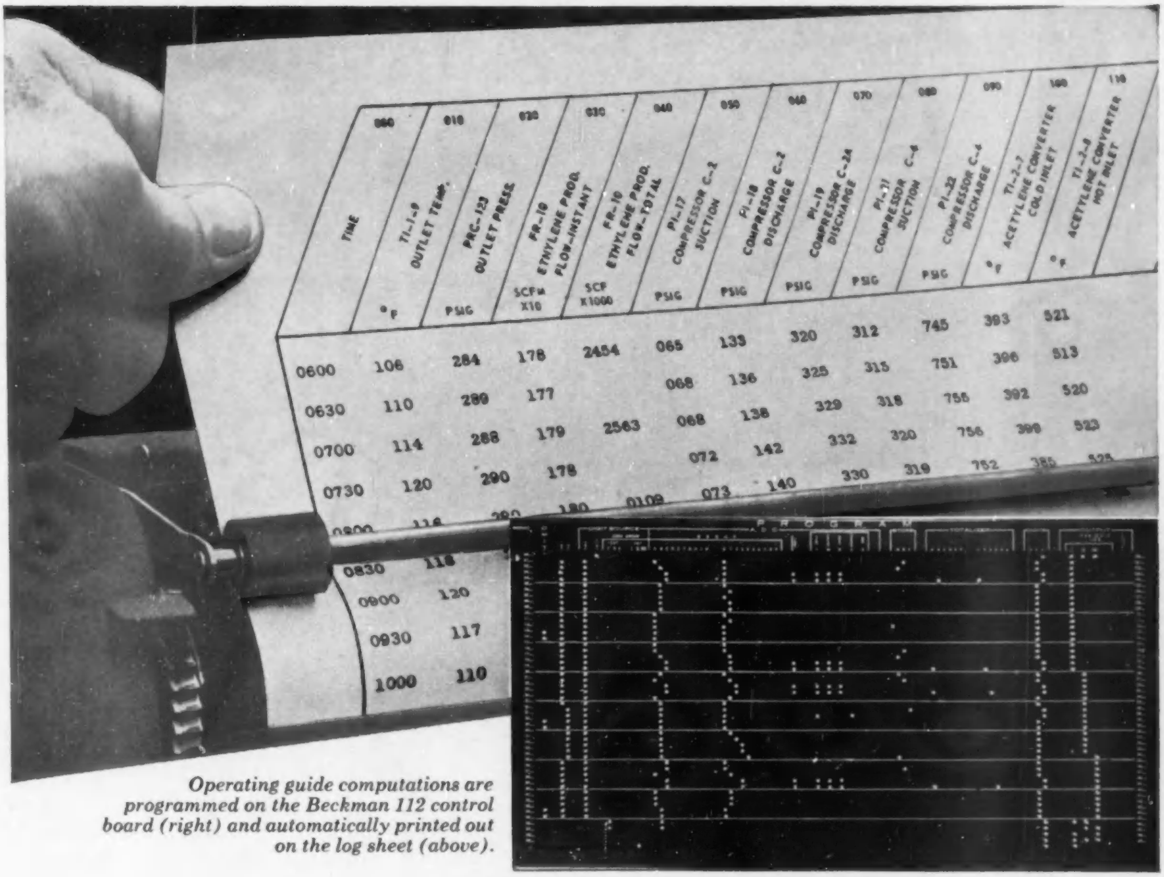

Operating guide computations are programmed on the Beckman 112 control board (right) and automatically printed out on the log sheet (above).

Continuous Control...with Computed Data

All the computing ability required for practical process control is provided in a single "package" by Beckman data processing systems. Developed specifically to meet the realistic needs of industrial control, Beckman systems incorporate an exclusive versatility that permits many analog and digital computations without a separate computer installation. The Beckman/112, for example, can supply computed operating guides as part of the logging cycle.

The pinboard and log sheet shown above illustrate the programming and readout of the system when absolute values of pressure and temperature are computed from measured gas flow data. More complicated computations, such as the calculation of carbon-burning rate, catalyst circulation rate and similar key process variables, are programmed in a similar manner. Without any need for additional computing capacity, the Beckman/112 can routinely solve such equations as

$$\frac{W/Q\sqrt{A\ [F(X) \pm B]\ + S}\ \pm Y}{Z}$$

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Beckman® *Systems Division*

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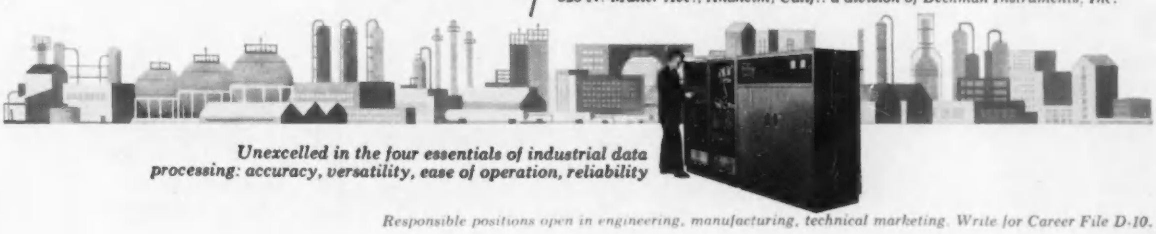

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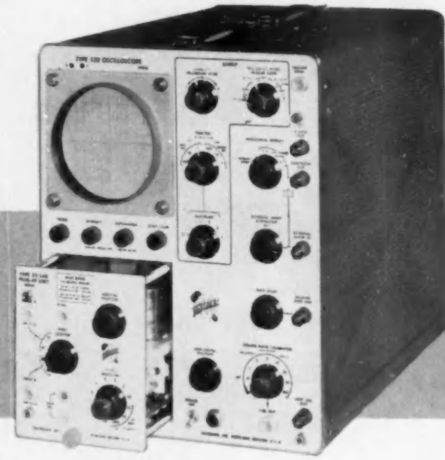


Type 53/54B—dc-coupled, 0.05 to 20 v/cm; ac-coupled, 5 mv/cm to 20 v/cm..**$125**

It's the plug-in preamplifiers that make this dependable oscilloscope outstanding in its class. With the Type 53/54B Plug-In Unit it can effectively cope with laboratory-oscilloscope applications that fall into the five-megacycle range, even when a high-gain vertical-deflection system is required.

The Type 532 becomes another oscilloscope when you plug in the Type 53/54D High-Gain Differential DC Unit, especially useful in industrial and other applications requiring slow sweeps and dc coupling at a deflection factor of one-millivolt per centimeter. It becomes still another oscilloscope when you plug in the Type 53/54E Low-Level Differential AC Unit, providing a vertical deflection factor of fifty-microvolts per centimeter for medical and other low-level applications. The Type 53/54C Dual-Trace DC Unit and the Type 53/54G Differential Wide-Band DC Unit are available to equip the Type 532 for these application areas, too. One oscilloscope . . . plus plug-in preamplifiers . . . adds up to true versatility.

Type 53/54D—1 mv/cm, dc to 350 kc; 50 mv/cm, dc to 2 mc **$145**

Type 53/54E—50 microvolts/cm, 0.06 cycles to 30 kc; 0.5 millivolts/cm, 0.06 cycles to 60 kc **$165**

CONDENSED SPECIFICATIONS

Wide Sweep Range
0.2 μsec/cm to 12 sec/cm
21 calibrated sweep rates
5x Magnifier

DC-Coupled Output Amplifier
Less than 3 db down at 5 mc

4-KV Accelerating Potential
8-cm linear vertical deflection

Versatile Triggering
Amplitude level selection and Automatic Triggering

Amplitude Calibrator
Square wave, 0.2 mv to 100 v

DC-Coupled Unblanking

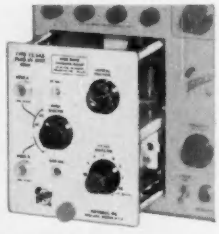
Electronic Voltage Regulation

Type 532 without plug-in units

$825

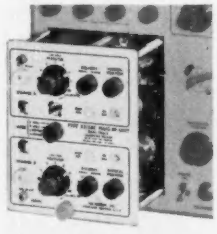
Prices f.o.b. Portland, Oregon

Please call your Tektronix Field Engineer or Representative for complete specifications.



Type 53/54A—dc-coupled, 0.05 to 20 v/cm.......**$85**

Type 53/54G—dc-coupled, 0.05 to 20 v/cm; differential input, high rejection ratio. **$175**



Type 53/54C—dc-coupled, 0.05 to 20 v/cm; two identical channels, electronic switching **$275**

ENGINEERS—interested in furthering the advancement of the oscilloscope? We have openings for men with creative design ability. Please write Richard Ropiequet, Vice President, Engineering.

Tektronix, Inc.

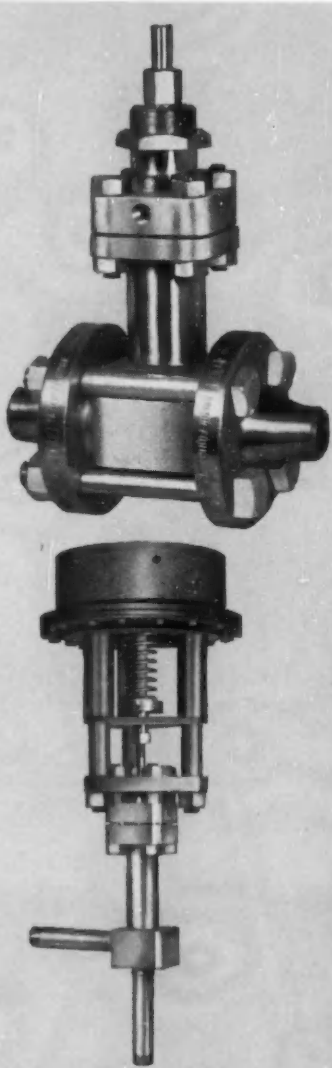
P. O. Box 831 • Portland 7, Oregon
Phone CYpress 2-2611 • TWX-PD 265 • Cable: TEKTRONIX

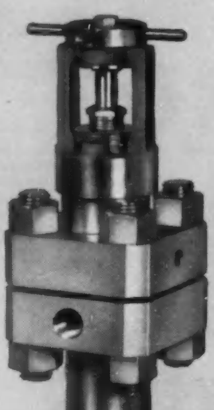
ANOTHER NEW IDEA FROM

FULTON SYLPHON

PACKLESS VALVES

YOU CONNECT AND FORGET





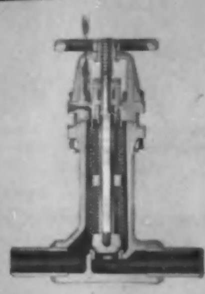
Some valves are good for severe corrosives, others for high pressures and temperatures, but these Fulton Sylphon Packless Valves are *complete* valves capable of mastering the toughest possible combination of conditions in atomic energy plants and grueling chemical processes. They assure utmost safety in handling hazardous materials, require no periodic maintenance, and practically eliminate down-time.

Typical of how Fulton Sylphon matches valve to process, these valves are made of stainless steel throughout, with the valve body machined as one unit from solid bar stock. And to prevent leakage or contamination, a SPECIAL SYLPHON® BELLOWS in multi-ply stainless steel forms a permanent, leak-proof seal for the stem. That is why they tame the severest corrosives inside and out. This is the reason, too, why these valves provide a high safety factor in high temperature-high pressure service.

These and other Fulton Sylphon Valves are available in many types, sizes, and metals—all with packless construction for greater safety, less maintenance and longer runs "on stream."

SEND TODAY FOR BULLETIN LW-813

A SPECIAL SYLPHON BELLOWS which forms the permanent, leak-proof stem seal on all Fulton Sylphon Packless Valves offers four outstanding features. It is (1) cold-worked for greater resiliency and longer life, (2) seamless, without welded seams to break and leak, (3) formed in multi-plies for greater strength, and (4) made in the right metal for service requirements.



Mr. Controls

Robertshaw-Fulton

CONTROLS COMPANY

FULTON SYLPHON DIVISION · Knoxville 1, Tennessee

INSIDE PERFORMANCE

OUTSIDE PROTECTION

against water, vapor, dust and time

POTPOT*

POTENTIOMETERS

Select that Clarostat standard wire-wound or composition-element potentiometer (Series 10, 48M, 49M, 43, 37, 51 or 58) for superlative electrical and mechanical characteristics.

Then, if you wish a water- and vapor-tight housing, have it encapsulated. That's the Clarostat POTPOT encapsulated control. Completely sealed with exception of external shaft assembly and terminal ends. Special water-tight provision for shaft. Meets MIL-STD-202 Test Specification. Also necessary salt-spray, humidity and temperature cycling requirements of MIL-E-5272.

TECHNICAL DETAILS ON REQUEST

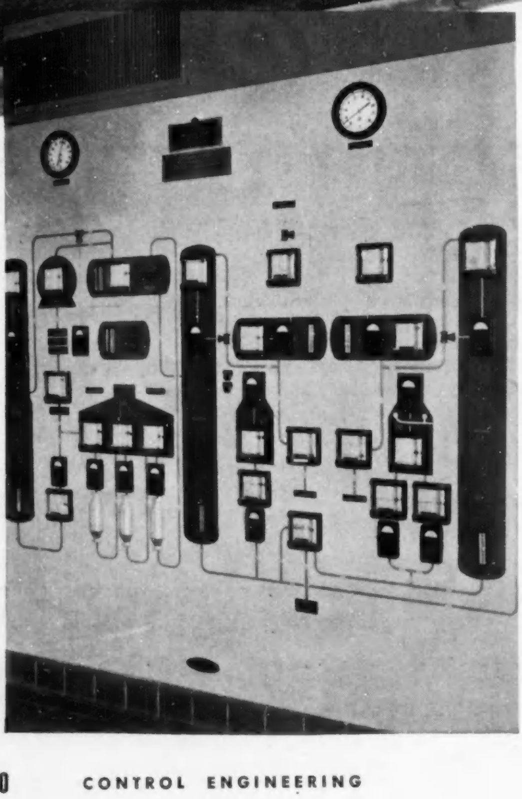
CLAROSTAT®

*Reg. U.S. Pat. Off.

CLAROSTAT MFG. CO. INC., DOVER, NEW HAMPSHIRE

In Canada: Canadian Marconi Co., Ltd., Toronto 17, Ont.

THIS REFINERY GOES ELECTRONIC...



Pontiac Refining Company in Corpus Christi installed a new reformer in 1956 to produce 100+ octane gasoline. Because distances from the control house to the process range up to 800 feet and some of the variables were difficult to control, 'American-Microsen' Electronic Instruments were selected.

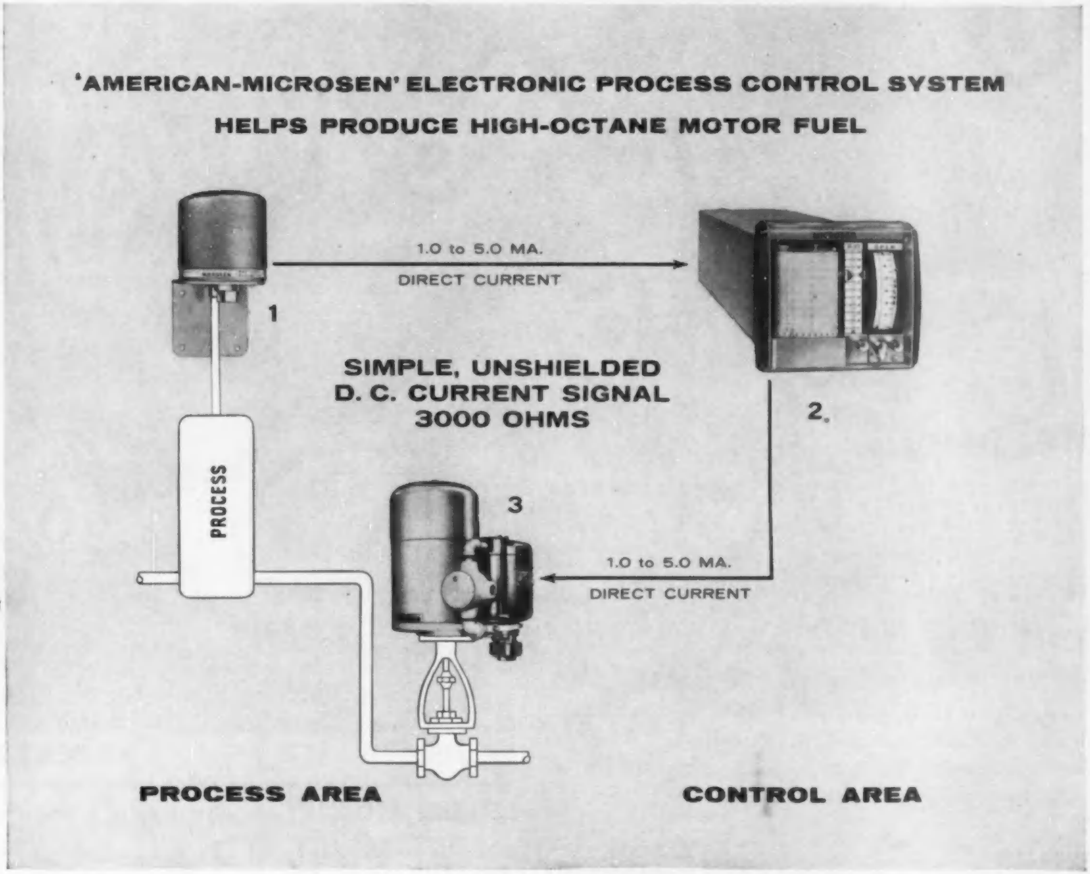
The control house contains 'American-Microsen' Controllers for pressures, flows, levels, and temperatures of the process materials at vital stages of the platforming process. Despite the long distances and fast-acting variables, the instruments provide control well within the tolerances required to produce high-octane motor fuel.

Such results are possible because the 'American-Microsen' System is completely electronic, with dc transmission signal that is insensitive to distances as great as 30 miles. The high speed and sensitivity of the electronic design improve the control of all process variables.

Now in operation over a year at Pontiac Refinery, the 'American-Microsen' System continues to give complete satisfaction — continues to help turn out high grade motor fuel. It is typical of many successful installations, and more and more companies are specifying the system for new plants as well as in modernizing existing processes.

Even though the electronics approach in process control is revolutionary, the 'American-Microsen' System of today incorporates the latest design techniques. Transistors are used for the ultimate in reliability and service life, and printed circuits and miniaturized components provide space-saving simplicity. The complete process control system now uses only three units.

the modern way to control process variables



1. **TRANSMITTER.** 'American-Microsen' transmitters are used for measuring pressure, temperature, differential pressure, liquid level, flow, and other process variables. The "Microsen" balance creates a stable dc signal for long distance transmission. Transmitters have a minimum of bearing pivots or linkages—assuring sensitivity and repeatability of measurement.

2. **CONTROLLER.** A single unit combines all functions of measuring and recording or indicating the input signal; producing the control signal; and allowing manual-automatic process operation. Separate plug-in chassis provides the following functions: A. Records or indicates process variable. Strip or card chart recorder chassis available. B. Produces proportional, reset and rate control actions to regulate the variable. All control settings are calibrated. C. Permits switching to manual operation during start-up or emergency conditions, with true "bumpless" transfer from manual to automatic control.

3. **ELECTRO-HYDRAULIC CONTROL VALVE OPERATOR.** A power unit with position feedback that operates slip-stem control valves. No compressed air is needed. Mountable on standard yokes supplied with conventional slip-stem control valves with bodies of single or double-seated construction, with V-port, parabolic, needle and equal percentage plugs, including valves of 4" stroke, and force available up to 3,250 lbs.

Where required, the 'American-Microsen' Electro-Pneumatic Valve Positioner or the Electro-Pneumatic Transducer can be supplied.

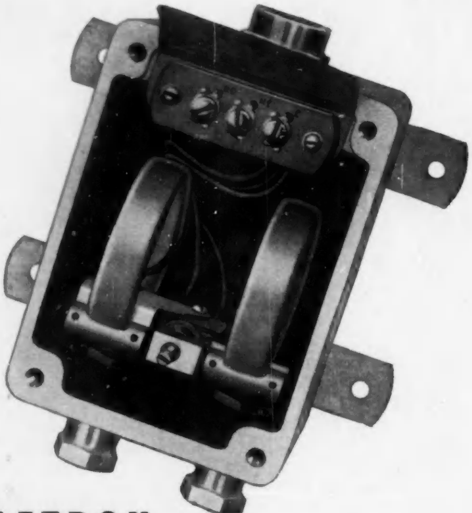
In automating your processes for higher product quality and greater operating economy, you want the better control and simplified servicing provided by the 'American-Microsen' Electronic Process Control System. We invite you to meet with one of our sales engineers to determine the best equipment for your service. Write for literature.

MANNING, MAXWELL & MOORE, INC.

MANNING MAXWELL & MOORE INC. TRADE MARK

INDUSTRIAL CONTROLS DIVISION • STRATFORD, CONNECTICUT

MAKERS OF 'AMERICAN-MICROSEN' ELECTRONIC INSTRUMENTS FOR MEASUREMENT, TRANSMISSION AND CONTROL



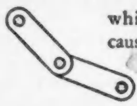
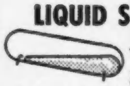
MELETRON

DIFFERENTIAL SWITCH

senses pressure differences from 4 to 9000 p.s.i.

with Proof Pressures ranging from 500 to 12,000 P. S. I.

A good illustration of this switch function is its application on multiple stage compressors. If a failure occurs in one of the stages the switch will signal the pressure difference change or shut down the system to prevent damage.

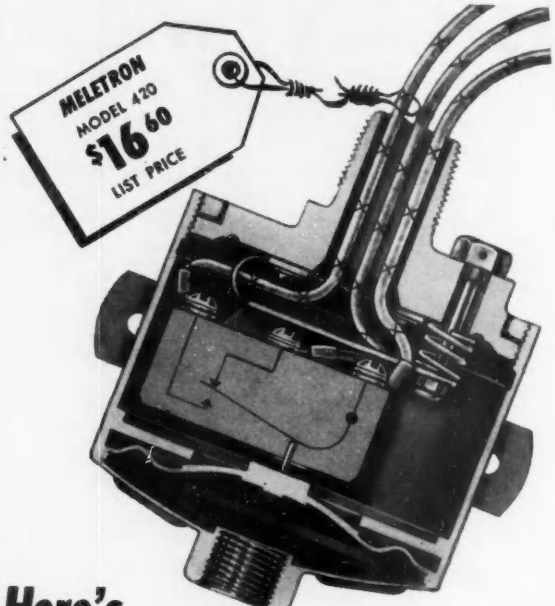
EXTREMELY ACCURATE Simplicity of direct acting design plus rugged precision construction make for long, unchanging repeat accuracy.	*Note, that we don't use* **LINKAGES AND BEARINGS** which, as they wear, cause settings to drift. 
IN ANY POSITION on moving equipment, even under vibration, switch performs with equal efficiency.	*Because we don't use* **LIQUID SWITCH ELEMENTS**  which require that the pressure switch be mounted absolutely vertical, which make it very critical to vibration.

To get complete operating characteristics and specifications ask for bulletin 532

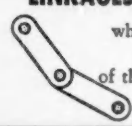
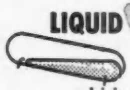
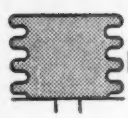
BARKSDALE VALVES

PRESSURE SWITCH DIVISION

5125 Alcoa Avenue, Los Angeles 58, California



Here's the Simplest Diaphragm Pressure Switch

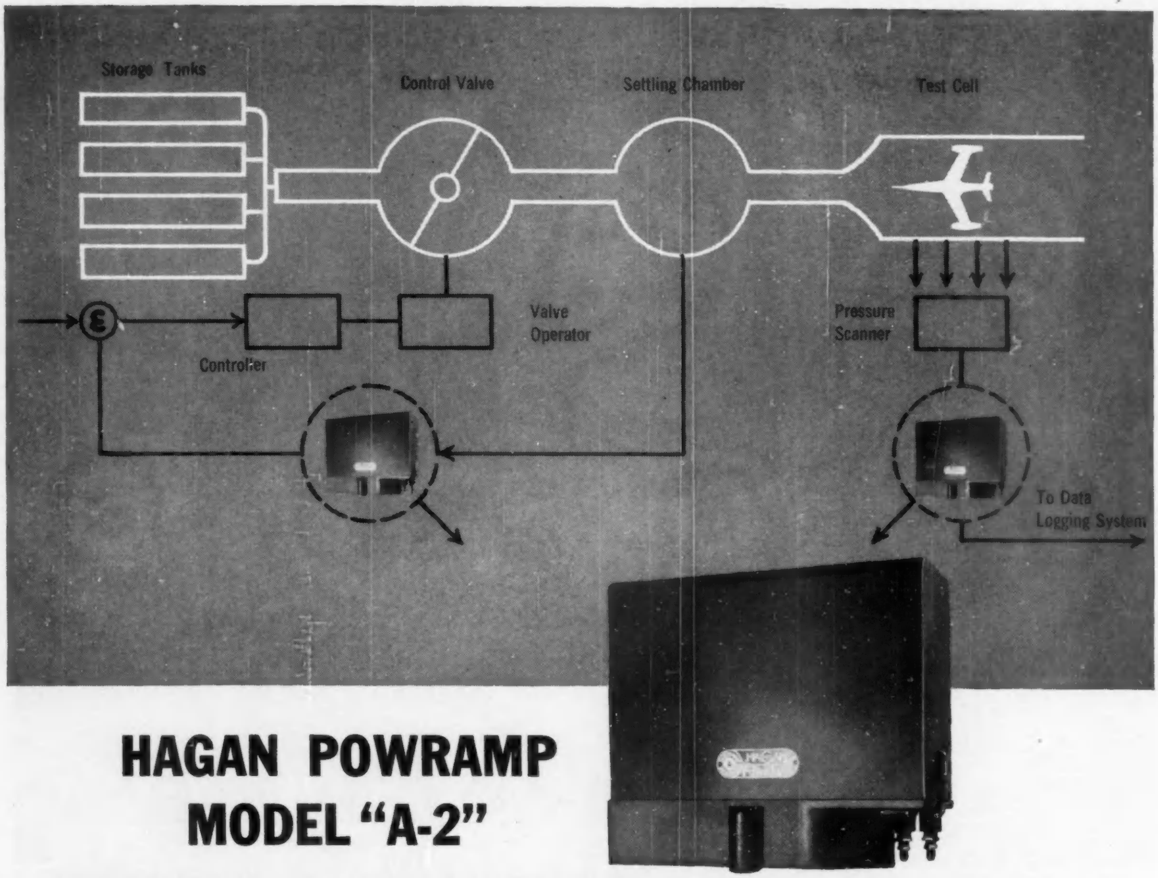
WE BUILD IN	WE DON'T USE
EXTREME ACCURACY and DEPENDABILITY maintained during operating life due to direct acting design	**LINKAGES & BEARINGS**  which, as they wear, make the setting of the pressure switch drift.
OPERATION IN ANY POSITION which saves the installation costs encountered in mounting a switch that uses liquid switching elements.	**LIQUID SWITCHING ELEMENTS**  which make the switch difficult to mount and very critical to vibration.
IMMUNITY TO VIBRATION you can mount the switch directly on your vibrating or moving equipment.	 **ACCORDION DIAPHRAGMS** which make the pressure switch sensitive to vibration.

To get complete specifications and operating data ask for bulletins 420- 421

BARKSDALE VALVES

PRESSURE SWITCH DIVISION

5125 Alcoa Avenue, Los Angeles 58, California



HAGAN POWRAMP MODEL "A-2"

PRESSURE TRANSDUCER

ACCURACY, 0.1% OF FULL RANGE — RESPONSE, 40 CPS — SENSITIVITY, .01% OF FULL RANGE

Up to ten times more accurate than conventional "displacement type" transducers, the Hagan PowrAmp Model A-2, with its companion amplifier, produces a dc output signal directly proportional to the input pressure. Available full scale ranges include absolute and differential ranges from 6 to 240 psi and gauge pressure ranges from 6 to 2000 psi.

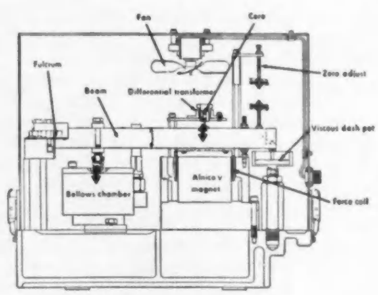
The Model A-2 is a fast feed-back, force-balance pressure pickup, with very low drift characteristics. The high speed and extreme accuracy of the Model A-2 make it ideal for use in electronic control systems where precise measurement is critical, or in single or multiple pressure readout systems.

Hagan PowrAmp transducers for most key variables, electro-hydraulic servo valves and electronic control computers are available as components or as units in engineered systems. Bulletin MSP-133, which describes the full line of Hagan PowrAmp components will be sent on request.

For additional information on the A-2 Transducer write for Specification Sheet PE-5000

HAGAN CHEMICALS & CONTROLS, INC.

HAGAN BUILDING, PITTSBURGH 30, PENNSYLVANIA
DIVISIONS: CALGON COMPANY · HALL LABORATORIES



SPECIFICATIONS OF MODEL A
(with companion amplifier)

Output	0-25 Volts or 3-28 Volts dc
Output Impedance	Approximately 100 ohms
Resolution Sensitivity	.01% Full Scale
Linearity	.05% Full Scale
Overall Accuracy	0.1% Full Scale
Frequency Response	Flat to 40 CPS
	Phase Shift at 16 CPS—5° Lagging

Now a standard line

POWERSTAT®

VARIABLE TRANSFORMERS for HIGH FREQUENCY APPLICATIONS

HS SERIES

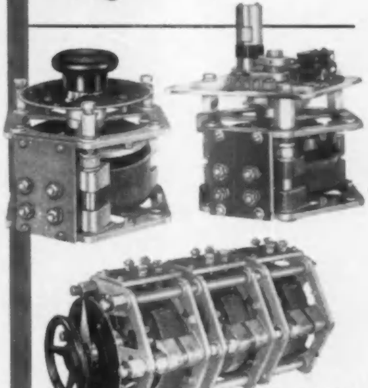
— ⅓ the weight — ½ the size of 60 cycle units

Designed for use in high frequency control systems where weight and space must be minimized, these POWERSTATS are ideal for ship, aircraft, guided missile and other 400/800 cycle applications.

Listed are some of the standard line of POWERSTATS for high frequency applications. However, many high frequency requirements necessitate designing to individual needs. The Superior Electric Company will be pleased to work with you on the design of POWERSTATS to satisfy new or unusual needs.

HM SERIES

INPUT		OUTPUT				MANUALLY-OPERATED MODELS				MOTOR-DRIVEN MODELS				
VOLTS	FREQUENCY CYCLES PER SECOND	VOLTS	MAXIMUM AMPERES	MAXIMUM KVA	TYPE OF CONSTRUCTION	TYPE	METHOD OF TURNING	APPROX. WEIGHT (POUNDS) NET	SHIPPING	TYPE	STANDARD MOTOR-DRIVES	SPEED OF TRAVEL IN SECONDS	APPROX. WEIGHT (POUNDS) NET	SHIPPING
SINGLE PHASE														
28	400/800	0–28	2.0	.056	Open	3HS02UK	Knob	0.5	0.9					
28	400/800	0–28	4.0	.112	Open	3HS04UK	Knob	0.8	1.2					
120	400/800	0–120 or 0–140	1.0	.14	Open	1HS01UK	Knob	0.9	1.3					
120	400/800	0–28	2.6	.073	Open	1RHS03UK	Knob	0.6	1.0					
120	400/800	0–120 or 0–140	3.0	.42	Open Square Frame	1HMS03UK	Knob	2.4	2.8	DM1HMS03U	28 Volt D-C	60	4.5	5.1
										AM1HMS03U	120 Volt A-C, 400 Cycles	60	4.5	5.1
120	400/800	0–120 or 0–140	7.5	1.0	Open Square Frame	1HMS07UK	Knob	3.4	3.8	DM1HMS07U	28 Volt D-C	60	5.5	6.1
										AM1HMS07U	120 Volt A-C, 400 Cycles	60	5.5	6.1
120	400/800	0–120 or 0–140	15.0	2.1	Open	1HL15UK	Knob	11.4	14.0	DM1HL15U	28 Volt D-C	60	13.2	16.2
										AM1HL15U	120 Volt A-C, 400 Cycles	60	13.2	16.2
240	400/800	0–240 or 0–280	3.0	.84	Open Square Frame	2HMS03UK	Knob	3.4	3.8	DM2HMS03U	28 Volt D-C	60	5.5	6.1
										AM2HMS03U	120 Volt A-C, 400 Cycles	60	5.5	6.1
240	400/800	0–240 or 0–280	9.0	2.5	Open	2HL09UK	Knob	12.8	15.4	DM2HL09U	28 Volt D-C	60	14.6	17.6
										AM2HL09U	120 Volt A-C, 400 Cycles	60	14.6	17.6
THREE PHASE														
240	400/800	0–240 or 0–280	3.0	1.5	Open	2HMS03UK-3Y	Knob	7.6	8.5	DM2HMS03U-3Y	28 Volt D-C	60	9.3	10.5
										AM2HMS03U-3Y	120 Volt A-C, 400 Cycles	60	9.3	10.5
240	400/800	0–240 or 0–280	7.5	3.6	Open	2HMS07UK-3Y	Knob	10.6	11.6	DM2HMS07U-3Y	28 Volt D-C	60	12.3	13.6
										AM2HMS07U-3Y	120 Volt A-C, 400 Cycles	60	12.3	13.6
240	400/800	0–240 or 0–280	15.0	7.3	Open	2HL15UK-3Y	Knob	34.5	41.0	DM2HL15U-3Y	28 Volt D-C	60	38.0	45.0
										AM2HL15U-3Y	120 Volt A-C, 400 Cycles	60	38.0	45.0
480	400/800	0–480 or 0–560	3.0	2.9	Open	4HMS03UK-3Y	Knob	10.6	11.6	DM4HMS03U-3Y	28 Volt D-C	60	12.3	13.6
										AM4HMS03U-3Y	120 Volt A-C, 400 Cycles	60	12.3	13.6
480	400/800	0–480 or 0–560	9.0	8.7	Open	4HL09UK-3Y	Knob	39.0	45.5	DM4HL09U-3Y	28 Volt D-C	60	42.5	49.5
										AM4HL09U-3Y	120 Volt A-C, 400 Cycles	60	42.5	49.5



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MICRO SWITCH Precision

...FIRST IN PRECISION SWITCHING

Over 200 MICRO SWITCH Precision Switches help make Lockheed's C-130 Hercules a superb military plane

MICRO SWITCH Engineering Service cooperated with Lockheed engineers of the Georgia Division, Marietta, Ga., for five years in the designing, planning and manufacturing of this plane—the first propjet transport accepted by the U. S. Air Force.

Over 200 precision switches at strategic points perform important functions in the operation of this superb aircraft. Other MICRO SWITCH precision switches are employed in components for this plane supplied by other manufacturers. Still others provide important controls for the machine tools used in the building of the C-130 itself.

Whatever your design—be it aircraft, machine tools, or any type of industrial equipment—MICRO SWITCH components and MICRO SWITCH Engineering Service may help you make a good design even better.

MICRO SWITCH reputation for reliability, precision and performance is written in the success of such products as the Lockheed Hercules and thousands of fine industrial products. MICRO SWITCH Engineering Service is as close as your telephone. Why not call the nearest branch office today?

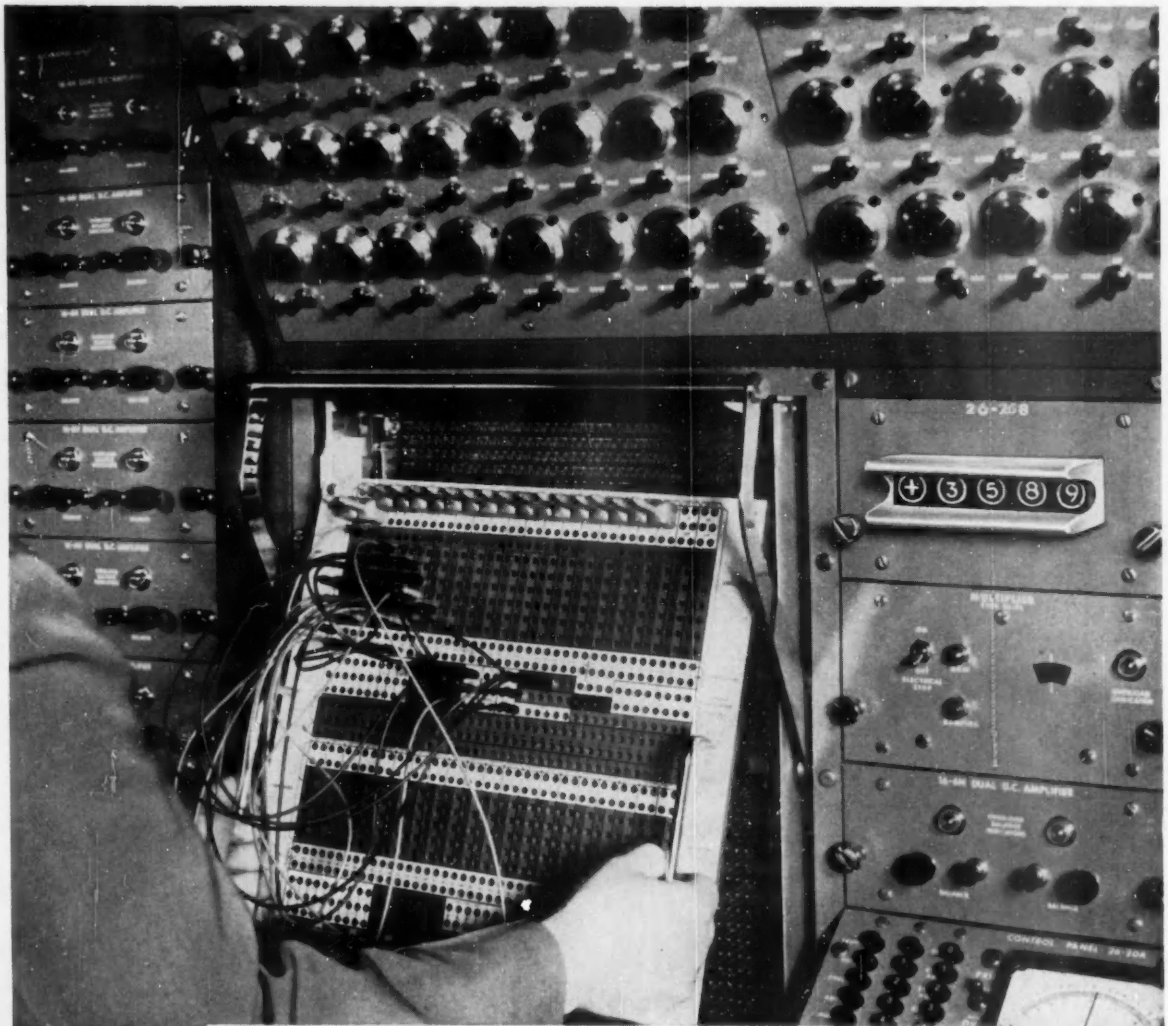
Wide variety of switch types in the Hercules

Series VA Enclosed Switches
These combine the features of sealed construction and high electrical capacity. They are available with roller arm or lever actuators.

Series V3 Basic Switches
These have the highest electrical capacity for their size of any switch available. Are available in wide variety of terminal designs, contact arrangements and operating characteristics.

Series SE Sealed Subminiature Switches
These are the smallest and lightest completely environment-free precision switches available. They are built to give trouble-free operation in a temperature range of from −65°F to +212°F.

Series DT Double-Pole Double-Throw Switches
These switches simultaneously make and break two independent circuits. The double-pole double-throw switches are rated for 10 amps. 125 or 250 v ac; ½ amp. 125 v dc; ¼ amp. 250 v dc. Temperature rise limits maximum continuous current to 10 amperes per pole.



ANOTHER FIRST FOR EAI
AN ELECTRONIC DIGITAL VOLTMETER

The new electronic Digital Voltmeter, Model 26-26B from Electronic Associates, Inc., enables readouts at speeds formerly thought impossible.

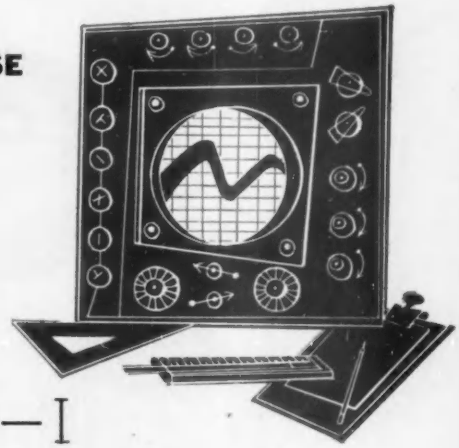
A unique transistorized digital comparator converts analog inputs to the binary coded decimal system in an average time of 0.05 seconds. Delays in readout time are reduced by a factor of 100. Readout accuracy is maintained at 0.01 Volts.

These advances are made possible because of this Digital Voltmeter's completely electronic and transistorized design. The progressive measuring and digitizing circuitry requires no moving parts at all. This results in extreme speeds, noiseless operation, and the greatest reliability.

The Digital Voltmeter is another first in EAI's Program of PACE. For complete details on this, and on any of the Computation Centers maintained by Electronic Associates, Inc. in Princeton, N. J., Los Angeles, California, or Brussels, Belgium, write to: Electronic Associates, Inc., Long Branch, New Jersey, Dept. CE-6.

ELECTRONIC ASSOCIATES Incorporated · EAI SETS THE P A C E PRECISION ANALOG COMPUTING EQUIPMENT ®

LONG BRANCH • NEW JERSEY



New Centers for Control—I

Control business is mushrooming in the vacation lands of Florida and Arizona—two states relatively new to the instrumentation field. Both credit guided missile development work for the phenomenon. But behind the missile activities are two other factors: 1) the establishment of a government research or test facility, and 2) the importance employees—particularly engineers and scientists—these days attach to pleasant living surroundings in a mild climate.

Florida romance

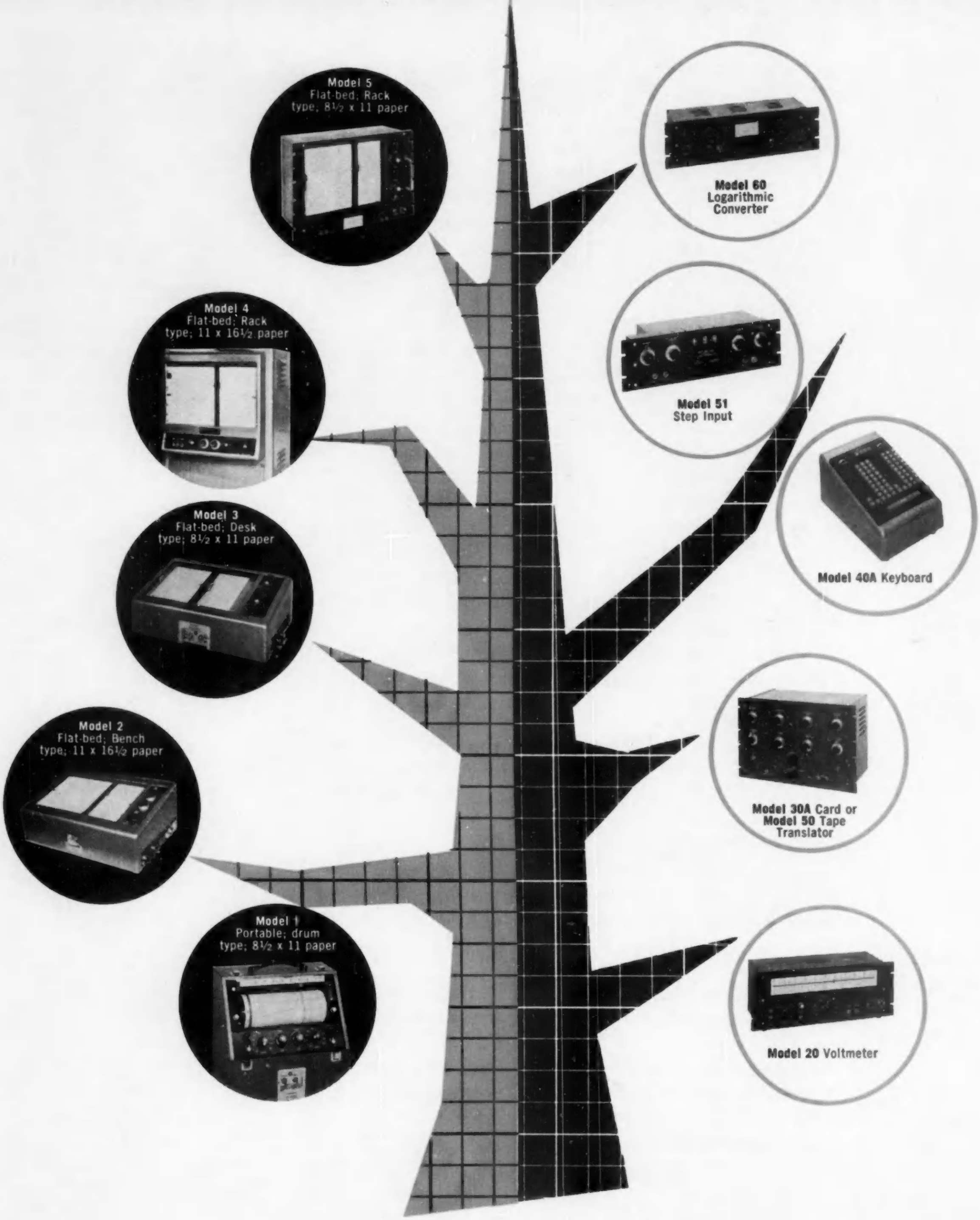
Last month, McGraw-Hill's Atlanta News Bureau Chief, Charles Dixon, filed this report after touring Florida activities:

> *"The state of Florida is involved in a torrid romance with manufacturers and researchers in the field of instrumentation and automatic control. The industry is just the type the state prefers to swell its nonagricultural working force. There's no 'smokestack' problem and the caliber of employees drawn by these companies practically insures an increase in the number of responsible citizens.*
>
> *"Contented instrumentation people in Florida confidently predict that the Sunshine State will be one of the top centers of control activity within the next ten years."*

The interest in controls in Florida can be traced back to the Defense Dept.'s reactivation of the Banana River Naval Air Station at Melbourne, Fla., as Patrick AFB. Patrick was designated the missile flight test center for all services. Since those early days, the center has grown from almost nothing to king size employing 10,000 people. And guided missiles have colored the Sunshine State's industrial progress.

Missiles and palm trees

Just about every company in the missile business has had to send some contingent to Melbourne; that includes Lockheed, Convair, Martin, Northrop, Hughes, etc. And many suppliers of missile test equipment, tracking gear, data processing and reduction equipment have stationed engineers nearby to help install and operate their products. One development stemming from activity at Patrick is the Martin Co.'s decision to build a 500,000-sq-ft electronics and guided missile plant on the outskirts of Orlando, about 60 miles from Melbourne. (The army's first production of surface-to-surface Lacrosse missiles came from temporary Martin facilities near Orlando.) And Hughes Aircraft Co. has had plans for several months for


Model 5
Flat-bed; Rack
type; 8½ x 11 paper
Model 60
Logarithmic
Converter
Model 4
Flat-bed; Rack
type; 11 x 16½ paper
Model 51
Step Input
Model 3
Flat-bed; Desk
type; 8½ x 11 paper
Model 40A Keyboard
Model 2
Flat-bed; Bench
type; 11 x 16½ paper
Model 30A Card or
Model 50 Tape
Translator
Model 1
Portable; drum
type; 8½ x 11 paper
Model 20 Voltmeter

a big plant to turn out missile control systems in the northern part of the state.

Recruiting is a pleasure

But recently, there's been another dynamic force behind the move to Florida. That's Florida's reputation as a vacationland with a story-book climate. Company after company will testify that Florida is a magic word when it comes to recruiting. Here are just two examples. When GE announced plans to build an X-ray equipment plant in St. Petersburg, 7,000 people applied for the 700 jobs offered. Pratt & Whtney, building a $24-million jet-engine plant at West Palm Beach, offered a choice of four locations in its advertising for engineers—Florida, California, the midwest, and New England. Florida drew 25 applications for every other one received.

Chamber of Commerce people point out that the bulk of the growth has been with well-established companies. GE plans an electronics plant near Gainesville as well as the X-ray factory. At St. Petersburg, Sperry Rand is ready to start work on a $2-million plant to fabricate radar and missile instrumentation. Most exciting news in recent years in Pinellas County (St. Petersburg-Clearwater area) was that Minneapolis-Honeywell would produce inertial guidance systems in a new 207,000-sq-ft plant that will employ 4,000 people and cost $4-million.

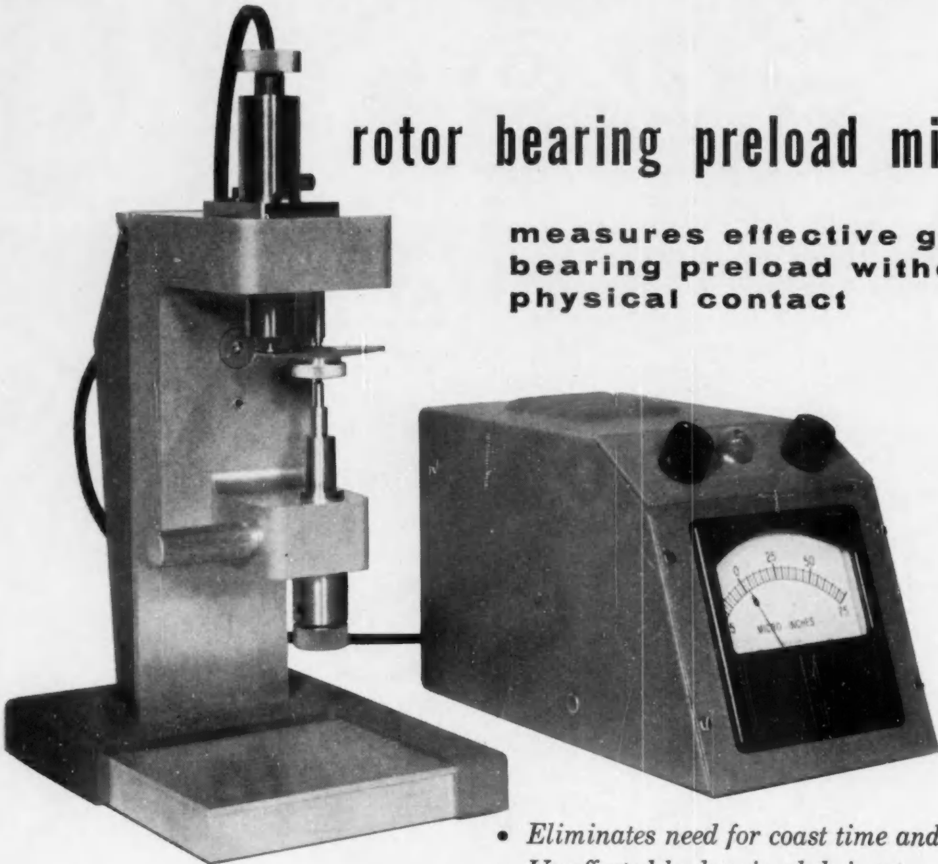
From Arizona, McGraw-Hill Newsman Frank Gianelli sends an on-the-spot report of mushrooming activity:

Arizona boom

"Phoenix is the hub of a rapidly expanding control industry that has spread all over the state. One banker explained the boom this way: 'You can't find anything wrong with Arizona. All the ingredients are available for a tremendous industrial empire. All it needs is time.'

"Population in Arizona is increasing at a phenomenal rate. Phoenix currently claims 600,000 residents; it expects to reach a million in 5 years. Tucson reports a figure of 150,000; it expects to pass 250,000 by 1962.

"There is one dark cloud in sight, however. That's a shortage of key engineers and scientists. There were only 100 electrical engineers in Arizona in 1940. By last year the number had increased to 1,200. The State Labor Dept. worries about estimated deficits in engineers available from Arizona sources. It figures that 56 percent of additional engineers will have to come from outside the states; 54 percent of additional mechanical engineers will



rotor bearing preload micrometer

measures effective gyro rotor bearing preload without physical contact

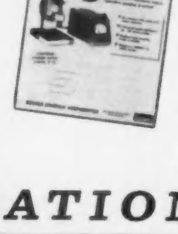
- *Eliminates need for coast time and acceleration tests.*
- *Unaffected by bearing lubricant.*
- *Amazingly compact and portable.*
- *Rugged construction for production line service.*
- *Sensitivities as high as .000005 inch per division.*

THE DECKER MODEL 104-1 ROTOR BEARING MICROMETER provides a positive and accurate means of measuring effective bearing preload . . . a prime factor in rotor performance.

Accurately measuring axial movements to known standards, the micrometer simplifies one of the most difficult jobs in rotor assembly . . . obtaining prescribed bearing preload. Benefits gained include a reduction in rotor assembly time... less need for skilled labor . . . no chance of bearing damage during run-in . . . and fewer rejections due to improper preload.

Simple adapter assemblies quickly convert the unit for handling many types of rotors, ranging in size from less than ½″ diameter to 3¼″ diameter.

Complete information on this unique new instrument is in Data Sheet 104-1, available upon request to the Technical Literature Section.



DECKER AVIATION CORPORATION

Philadelphia, 25

have to be imported. And no industrial engineers are now being trained in Arizona.

"The impetus of industrial activity is reflected in curriculum changes at Arizona State College (at Tempe), which has added emphasis on electronics and other engineering courses. An IBM computer was just installed with the cooperation of GE, which wanted such an installation for its nearby, newly completed Computer Div."

Army move

The hustle and bustle in Arizona control can be traced back to the transfer there of the U. S. Signal Corps big Fort Huachuca proving grounds. Electronic and control makers followed.

In Phoenix, Motorola has built three facilities—two for manufacturing missile parts and transistors and one for research—in the past eight years. Just recently, GE established its Computer Div. there (after checking 187 other U. S. cities); Sperry Rand has set up in Phoenix to produce missile and aircraft parts; and Goodyear Aircraft's five year-old plant is now producing missile components in this city.

The climate is the thing

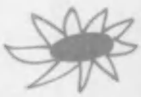
Plant location investigators claim that Phoenix has one of the best living climates—and business climates, too—in the U. S. There's lots of sunshine and leisure-time facilities—and land costs for industrial sites are reasonable. One other attraction: builders say they offer more house per dollar—with more square feet of "livability"—than any other place in the country.

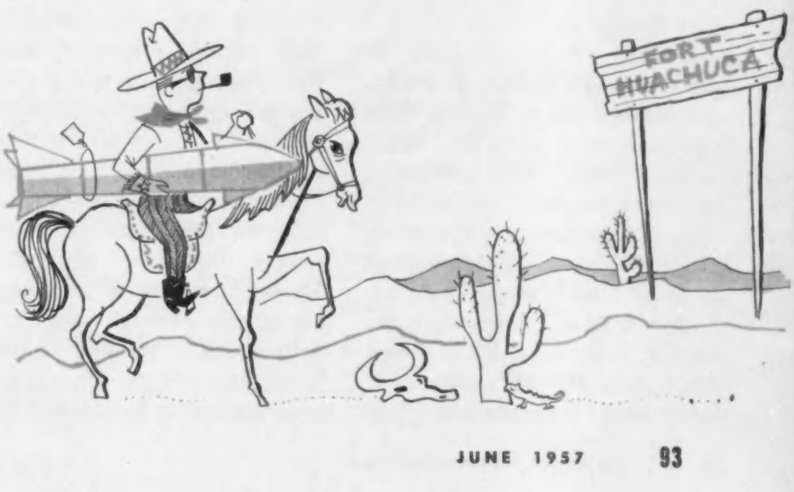
Growth at Tucson has been even more recent. For a couple of years, Tucson was a one-plant city, dependent on the big Hughes missile control facility. But now Douglas Aircraft has moved in and so has the Armour Research Foundation.

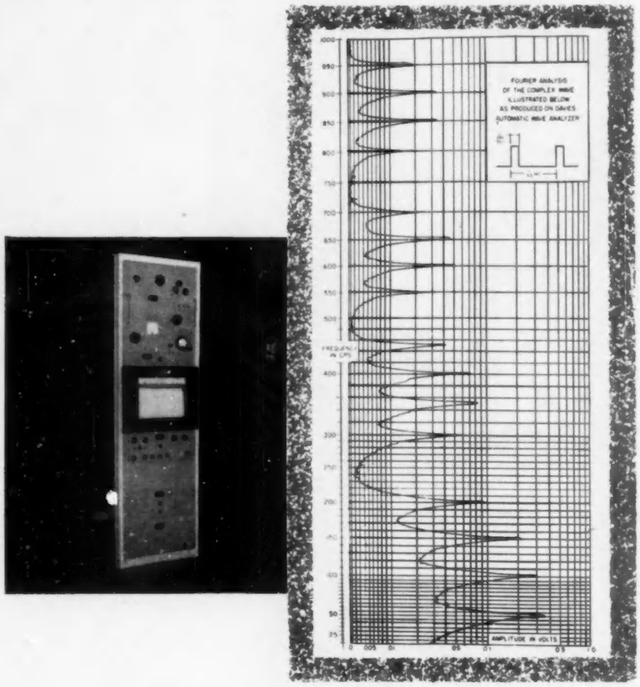
Tucson residents like the type of industrialization the control industry provides: park-like plants, no smoke to generate smog conditions, good pay, and air-conditioned working quarters to combat summer temperatures.

Plus factors

All these plus-factors, say the newly established businesses, outweigh some disadvantages: inaccessibility to markets, supplies and subcontractors, and a low rating in technical training and transportation. And the outlook for these disadvantages is sharp improvement. (Next month CONTROL ENGINEERING looks at two more burgeoning control markets.)







Once the data is on magnetic tape, there still remains the job of analyzing it. You can convert it to digital values, manually measure and sample it, and feed it to a digital computer on punched cards . . . but that takes considerable time and effort by skilled personnel. Rather than limit the number of analyses taken and the length of samples analyzed, labs are turning to direct analog analysis, which merits consideration by speeding reduction . . . permitting larger samples . . . increasing statistical reliability.

how automatic wave analyzers speed analog data reduction, improve statistical reliability

Automatic wave analysis is probably the least complicated technique for reducing analog data. Feed the taped data to an analyzer, flip the switch, and a complete Fouriér series is automatically plotted and printed in permanent record form. There are no intermediate steps, and what little the operator has to do can be trusted to relatively unskilled personnel.

Both of the two models available from Davies can accurately plot Fouriér series data as either *amplitude* versus *frequency* or *power* versus *frequency* at the flip of a selector switch. Both are also equipped with a "quick look" facility. Model 9020A provides a quick analysis across its frequency range of 3 cps. to 2 kc in 6 minutes; Model 9050A across its range of 3 cps. to 10 kc in just 15 minutes. Linear or square law output, as desired, is recorded by a Brown *ElectroniK* Potentiometer as a large, easily readable plot. You can visualize results immediately without any further curve tracing.

Multichannel inputs permit you to analyze as many as seven channels of data simultaneously. But the ultimate in automation is provided by the addition of a Davies Automatic Channel Selector, which you can program for serial analysis of up to 14 channels, changing tape speed, bandwidth, and output as you desire . . . all without any further attention.

It must be conceded that, while Davies Analyzers do provide high amplitude accuracy across wide frequency ranges, no analog analysis equipment could provide the *point* accuracy of manual and digital computer methods. But too often, that point accuracy is only achieved at the expense of reliable results. The speed with which Davies Automatic Wave Analyzers can run through data—in as little as 3% of the time required by digital methods—permits such large samples to be analyzed that the statistical reliability of the overall result remains unequalled.

That's why Davies Analyzers, first designed for aircraft studies, have since been successfully applied to vibration, noise, shock, and flutter analysis in vehicles, aircraft, missiles, and ships . . . seismic interpretation . . . powerline disturbance analysis . . . noise analysis . . . and any number of other phenomena characterized by randomly fluctuating data.

You'll find considerable additional information on Davies Automatic Wave Analyzers, how they operate, and what you can expect from them in the way of specific performance characteristics in Bulletin 9001. Write Minneapolis-Honeywell Regulator Co., Davies Laboratories Division, 10721 Hanna Street, Beltsville, Maryland, or call Webster 5-2700.

MINNEAPOLIS
Honeywell
DAVIES LABORATORIES DIVISION

Control
ENGINEERING
JUNE 1957

Why Not Joint R&D?

American industry is in the midst of a rapid expansion in technical research. The McGraw-Hill Dept. of Economics' latest survey of Business Plans for New Plants and Equipment: 1957-1960 reports that large companies plan to spend, on technical research, a total of \$7⅓ billion this year and \$9¼ billion in '60. Except for planned expenses of \$300 million in '57 and \$450 million in '60 for "professional and scientific instruments" (in the SIC's esoteric language), no one knows what portion of the billions will go for research in measurement and control. However, because developments in measurement and control are so intertwined with developments in machinery, missiles, and processes, two outcomes are clear – control R&D will require many more control engineers, and they will duplicate one another's work over and over.

We think that industry should examine this redundancy. Because technical R&D is a key to staying ahead of the other guy, each company does its own basic and applied research. However, if fundamental and/or common problems were tackled by joint and nonproprietary efforts, each company could spring from the results to its own applied research – with much less duplication of manpower. A few successes demonstrate the possibilities:

- ▶ A project sponsored at Case Institute by a "group of industrial organizations with a common interest" in control of optimum process performance by computer control systems
- ▶ Fluid metering research financed at Ohio State by ASME
- ▶ Research on mechanical pressure elements by ASME

As within ASME, there is machinery in AIEE for organizing and conducting research, although AIEE has no projects in measurement and control so far. We are told that IRE has no centralized research operation, but that its professional divisions have the freedom and funds for it. ISA is activating an R&D committee under W. A. Wildhack of the National Bureau of Science. It will recommend projects for the new Foundation for Instrumentation, Education, & Research and it will explore joint-society R&D.

What can you do? You can outline needs that you see for basic research to the chairman of the measurement and control division in your technical society. You can work for joint research by the technical societies.

THE EDITORS

Process-Control Problems Yield to the Analog Computer

The analog computer has given systems engineering a big boost over the older methods of design for process control systems in the chemical industry. Interestingly, the answer is still "cut-and-try", but the cut-and-try is now done in minutes by turning computer knobs instead of in months by changing actual control elements on the process. The savings in time and money are obvious. This article shows, step by step, how a batch chemical process and a control system proposed for it were set up and solved by simulation on an analog computer. Though it did not happen in this case, the computer might have shown the need for a change in the process itself to attain satisfactory control with practical instruments.

C. W. WORLEY, Electronic Associates, Inc., and
R. W. E. FRANKS and J. F. PINK, E. I. du Pont de Nemours & Co., Inc.

Chemical processes often present control problems that are unwieldy by the usual methods of solution. Such a problem arose recently in a batch heating operation, and it was decided that simulation of the process and its control system on an analog computer would produce an accurate answer in the quickest and least-expensive way. This article tells, step by step, how this simulation was done. The process described here is a good one to illustrate the method because it includes several interesting simulation problems and because its related batch operation is common in the process industries.

Description of the physical system

Physically, the problem involves only the batchholder (a large kettle with a jacket into which steam can be injected to heat the batch), its instrumentation, and the control system. Temperature is the unwieldly parameter in this case because of the strict process requirements that it follow as closely as possible the ideal temperature-time curve of Figure 1. Specifically, the batch enters the kettle with its temperature somewhat below 150 deg F, is heated as quickly as possible to about 200 deg F, at which it is held for a fixed time, and then is quickly cooled and sent on. A variation of only 1 deg F can cause off-standard product and losses.

The low temperature-overshoot required by the process makes adequate reproduction of the curve of Figure 1 impractical with manual controls. But automatic control introduces other problems. For one, the large thermal inertia of the batch controls the rate at which batch temperature rises after steam is admitted to the kettle jacket. For another, batch size can vary, which means a variable heat transfer lag. Also, the precise temperature to which the batch is heated can be changed according to process requirements, and steam and water supply pressures can fluctuate.

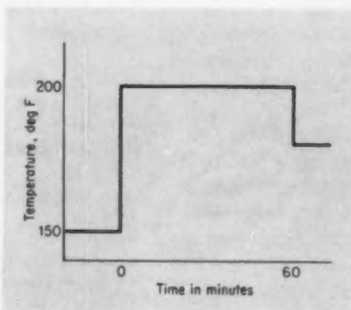


FIG. 1. Desired temperature response for batch process described.

Several questions arise at this point which are answered most easily by an analog simulation. For example:

► Is it possible to attain reproducible start-up conditions for every batch, with a maximum transient overshoot of less than ½ deg F?

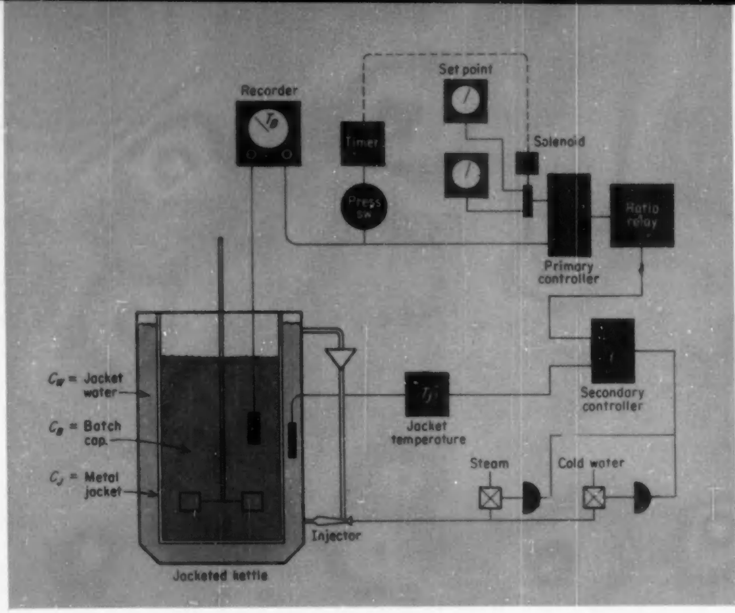


FIG. 2. Batch process and cascade-control systems.

- ▶ Is a cascade-control system superior to a single-loop control system? If so, by how much?
- ▶ What will be the optimum controller settings?
- ▶ How much will the system stability and reproducibility be affected by changes in steam pressure, batch size, ambient temperature, cooling water temperature, and batch reaction?
- ▶ Will controller drift be a serious problem in maintaining system response within the required limits?

The simulated system

Simulation of the batch operation with a cascade-control system will be described in detail in this article. Simulation of the single-loop system will not be described, since it is relatively simple.

In the cascade system, shown in Figure 2, the batch temperature is recorded and transmitted by the primary controller to adjust the set-point of the secondary controller. The secondary controller operates "dualled" valves to supply either cold water or steam to the jacket of the kettle. A ratio relay in the output of the primary controller limits the set-point signal applied to the secondary controller. Without this limit, the jacket wall would become excessively hot during warm-up when a large error exists, and thus would compromise product quality.

The primary measuring element in the batch is a resistance-bulb thermometer, chosen for its accuracy and reliability. It has a measured time constant of 4 sec. Its output is converted to a pneumatic signal and applied to the primary controller. This same pneumatic signal actuates a pressure switch that is preset to close when the holding temperature is reached. The pressure switch starts the timer that determines the holding period, and after this period the set-point of the primary controller is dropped to a lower temperature. This is done by a solenoid valve and two variable set-point pressure supplies.

Jacket temperature is measured by a capillary-type bulb placed within the jacket so as to measure an average temperature. Both controllers are pneumatic and have three adjustable modes—rate, automatic reset, and gain. Whether valves have equal percentage or linear trim would be determined by the analog study.

The computer solution

The usual reason for simulating a system by analogs is that the analog system is relatively inexpensive and quick to change, and obeys the same differential equations for its behavior in time as the original system. The early mechanical analogs have given way to the modern electronic analog computer primarily because the electronic analog elements are relatively noninteracting; i.e., they do not load one another and thereby cause changed dynamic characteristics. Electronic analogs also offer great flexibility in circuit arrangement, and are relatively inexpensive for high precisions. Although voltages at various points in the computer simulate forces, velocities, temperatures, etc., in the original system, the circuits also represent its differential equation; hence the term "computer".

Returning to the batch heating operation, the basic law of heat transfer by conduction can be expressed in the form of the rate of heat transfer:

$$\text{Rate} = \frac{\text{driving force}}{\text{resistance}}$$

The driving force is the temperature drop across the body, and the resistance is defined by Fourier's law:

$$\frac{dQ}{dt} = \frac{\Delta T}{\gamma} \tag{1}$$

where

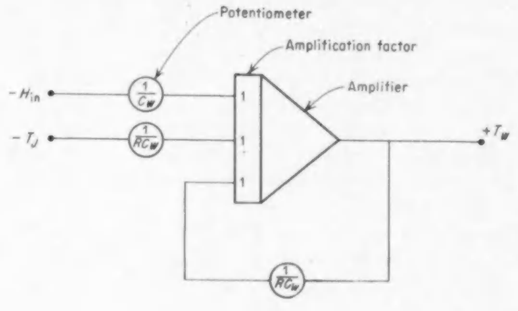
$\frac{dQ}{dt}$ = Rate of heat flow in Btu/min

ΔT = Temperature differential in deg F

γ = Thermal resistance in deg F/Btu/min

The similarity between Fourier's law and Ohm's

FIG. 3. Computer diagram for water-jacket section. The rectangle attached to the triangular amplifier symbol indicates that amplifier is connected as an integrator (feedback via series capacitance). Plus and minus signs indicate polarity of computer signal. Note that input signs are opposite to Equation 3A, because electronic integrator inverts signal.



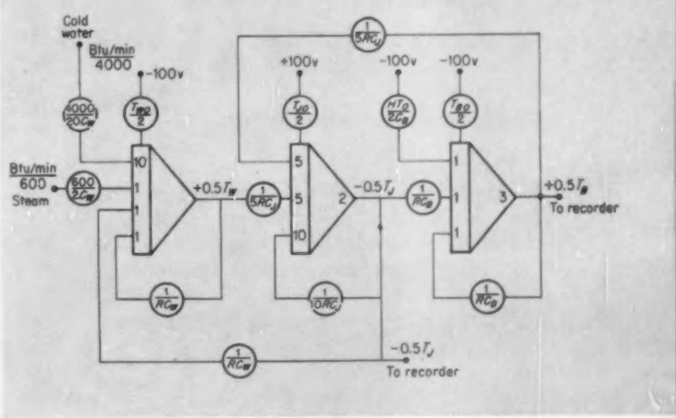


FIG. 4. Computer diagrams for entire jacketed kettle. Integrator outputs show scale factor of parameter as well as polarity.

law for electric current is immediately apparent, and an analog simulation is applicable. This similarity between heat flow and the flow of electricity (in a noninductive circuit) leads next to a definition of thermal capacity. Thermal capacity signifies the ability of a mass to store heat energy, and is determined by the specific heat of the substance. For example, the specific heat of water at standard conditions is unity; that is, if one point of water is raised in temperature by 1 deg F, 1 Btu will be absorbed. Therefore, by definition, the units of thermal capacity for a specific mass are:

$$C_{thermal} = \text{Btu/deg}$$

The thermal capacities used in this analysis, C_w, C_j, and C_b, are the heat capacities of the water jacket, the jacket wall, and the batch product respectively. To simplify these relations, the assumption of one-dimensional heat flow was made.

To be theoretically correct, heat flow, like the flow of electric current, must be represented by a system having parameters distributed throughout the body. Mathematical treatment of distributed parameter systems involves partial differential equations. To simplify the analysis, the assumption of "lumped" parameters was made by assuming uniform temperature distribution throughout each section of the process.

For the simplifying assumption of uniform temperature in the water jacket, the following heat balance equation can be written:

$$\underbrace{C_w \frac{dT_w}{dt}}_{\text{Heat stored}} = \underbrace{H_{in}}_{\text{Heat flow in}} - \underbrace{\frac{T_w - T_j}{R}}_{\text{Heat flow out}} \tag{2}$$

This first-order differential equation is a simple statement of the physical fact that the rate of change of the water jacket temperature T_w is proportional to the difference between the flow of heat entering and leaving the jacket.

Transposing Equation 2 for the rate of change of the water jacket temperature gives:

$$\frac{dT_w}{dt} = \frac{H_{in}}{C_w} - \frac{T_w}{RC_w} + \frac{T_j}{RC_w} \tag{3}$$

which can be set up directly on an analog computer (Figure 3) by integrating both sides*.

$$T_w = \int \frac{H_{in}}{C_w}\, dt - \int \frac{T_w}{RC_w}\, dt + \int \frac{T_j}{RC_w}\, dt$$

Using the same procedure, the heat-balance equation for the inner jacket wall can be written.

$$\underbrace{C_j \frac{dT_j}{dt}}_{\text{Heat stored}} = \underbrace{\frac{T_w - T_j}{R}}_{\text{Heat flow in}} - \underbrace{\frac{T_j - T_b}{R}}_{\text{Heat flow out}} \tag{4}$$

For the product batch

$$\underbrace{C_b \frac{dT_b}{dt}}_{\text{Heat stored}} = \underbrace{\frac{T_j - T_b}{R}}_{\text{Heat flow in}} - \underbrace{h(T_b - T_a)}_{\text{Heat flow out}} \tag{5}$$

These equations can be set up in exactly the same way as the one for the water jacket, but with different coefficient potentiometer values. These circuits, when connected as shown in Figure 4, yield the complete computer diagram for the process.

Since the control valves are arranged to admit both steam and cooling water to the water jacket, the heat input into the simulated process is made up of two components (shown in Figure 4). The coefficient potentiometers labeled $T_{wo}/2$, $T_{jo}/2$, and $T_{bo}/2$ establish initial process temperature at the start of the computation. The signal shown at the output of

* *Electronic Analog Computers*, Granino A. Korn and Theresa M. Korn, McGraw-Hill Book Co., Inc., New York, 1952.

the amplifier identifies the process variable at that point with its polarity and its scale factor.

Control valve simulation

The process temperature T_b is controlled by modulating the flow of steam or cooling water into the water jacket according to the output of an industrial pneumatic controller. This entrance of steam or cold water displaces equivalent quantities of water at temperature T_j. The control valves used to control these flows are diaphragm-operated and pneumatic, and are arranged to perform as in Figure 5.

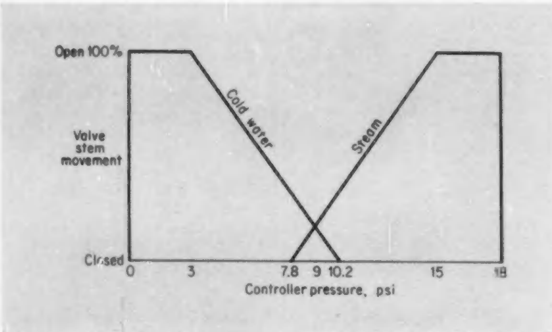


FIG. 5. Action of control valves vs. controller output pressure.

For controller output pressures from 3 psi to 10.2 psi, the cooling-water valve moves from full open to completely closed, while for pressures of 7.8 psi to 15 psi, the steam valve moves from full closed to full open. Thus, the response of each valve overlaps in the region of 9 psi.

The flow through a valve at a given opening is a simple function of the maximum flow (W_w) that can be delivered with the same pressure drop. This function can be simulated on an analog computer by using a servo multiplier, which is a servo-driven series of potentiometers. The controller pressure, represented as a machine voltage, drives a servo amplifier and motor to position the series of potentiometers according to a signal fed back from a reference voltage on one potentiometer. The voltage representing maximum flow is applied across another potentiometer and the actual valve flow is represented by the voltage fraction picked off by the arm position. To simulate equal percentage characteristics, the arm of the potentiometer is loaded with a resistor whose value is approximately one-tenth of the potentiometer resistance.

The computer circuit used to simulate the cold water and steam valve is shown in Figures 6A and B. In this case, P_c has been chosen to have an excursion of 75 volts, equivalent to 0—15 psi. From this input is subtracted the 7.8-psi voltage equivalent for the steam valve and the 3-psi voltage equivalent for the cold water valve, so no valve operation occurs when P_c is below these values. The diodes on the output of amplifier 31 limit its negative voltage output. This effectively "cuts off" the action of the cold water valve for P_c greater than 10.2 psi (Figure 5). Servo-driven potentiometers 2B and 2A will give the water flow and the heat flow respectively when the correctly scaled voltages are applied. To simulate the cold-water valve being fully closed for control pressures of 10.2 psi and above, the negative sides of potentiometers 2A and 2B are grounded.

A similar procedure applies for the steam valve. Amplifier 32 is biased by diodes to limit its output to 0 to minus 100 volts for controller output pressures from 7.8 to 15 psi.

The calculation of the voltages to be applied to the valve potentiometers can be illustrated with the steam valve. The heat content of steam at 50 psi is 1,174 Btu $= H_s$ and at a maximum flow of 10 lb per min for the valve wide open, gives a heat flow of 11,740 Btu min. This steam condenses and assumes the jacket-water temperature, the heat content of which is $10(T_w—32)$. Hence, heat liberated by steam to the jacket water is:

$$11{,}740 - 10\,(T_w - 32) = 12{,}060 - 10.0T_w$$
$$\text{or } W_sH_s - W_s\,(T_w - 32) = (W_sH_s + W_s\,32) - W_sT_w$$

Figure 6A shows the computer connections required to simulate the heat flow through the valve. The output voltage at the arm of potentiometer 4A constitutes the heat flow into the process (Figure 4) from the steam valve, divided by the scale factor of 1 volt = 600 Btu min.

A similar procedure is involved in scaling the heat carried away by the cold water. For this case the scale factor is 1 volt = 4,000 Btu min. This output is introduced to the process of Figure 4 through an attenuator.

Simulation of temperature transmitter

Tests have shown that the dynamic characteristics of the resistance bulb, instrument, and transmission can be approximated by two first-order lags with 4-sec time constants. The transfer function is:

$$\frac{P_c}{T_b}(s) = \frac{1}{(4s+1)\,(4s+1)}$$

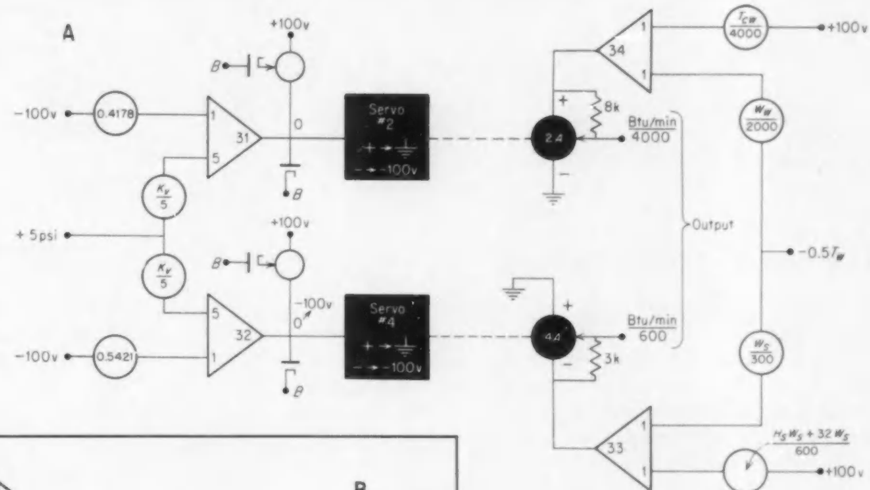
The performance of the temperature transmitter as described by this equation is easily simulated on the analog computer.

One of the advantages of analog computation is the ability to transform the time scale of a particular problem. In this process, transients up to 30 min are involved and a time-scale change of 60 to 1 has been made.

With the time scale change factor B=1/60, this transmitter transfer function becomes:

$$\frac{P_c}{T_b}(s) = \frac{1}{(4B_s+1)\,(4B_s+1)}$$

The computer circuit which is employed to simu-



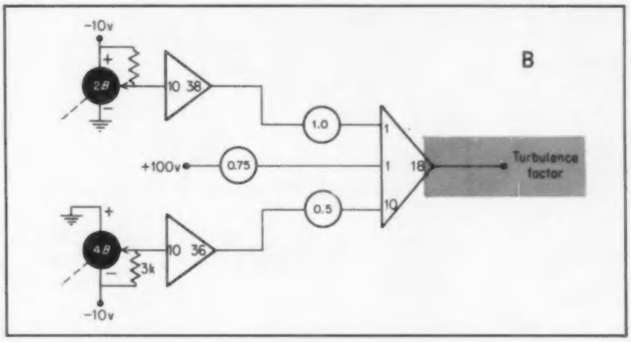


FIG. 6. A—Computer simulation of control valve flow rates; B—simulation of valve turbulence factor for input of water jacket temperature transmitter, Figure 8. Connections for positive and negative ends of servo-feedback pots are indicated on servo symbol. Points marked B on diodes are connected to input grid, placing diode across amplifier as a limiter.

late the temperature transmitter is shown in Figure 7.

The batch-temperature-transmitter output of 3-15 psi is the equivalent of 15-75 volts in the computer. The first amplifier is biased so that its output range is plus 42.5 to minus 40 volts for the entire range of T_b. The diode rectifier limits its output to 0 to minus 40 volts. Amplifiers 4 and 5 are connected as first-order lags with time constants of $B\tau = 1/15$-sec computer time. The last summing amplifier multiplies the 40 volts by 1.5 and adds a constant 15 volts (3 psi) to give the equivalent output pressure in volts.

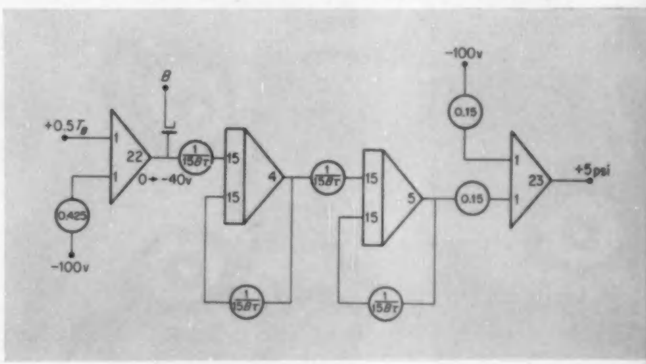
Jacket-water temperature

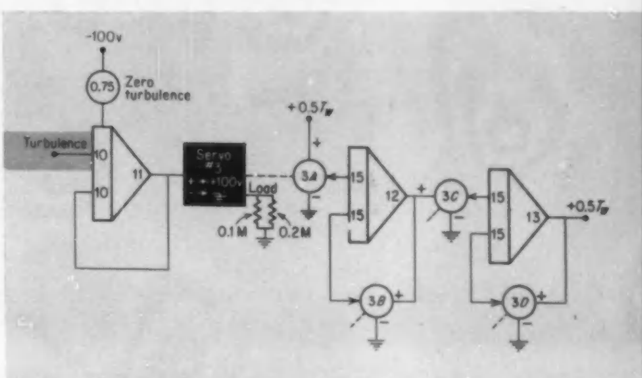
The jacket-water temperature transmitter transmits a 3-to-15-psi pneumatic pressure proportional to the water temperature. The range of this instrument is 0-250 deg F. Its dynamic characteristics can be represented by two first-order lags. However, the time constant varies with the amount of water turbulence, being approximately 4 sec for high turbulence and 6 sec with no turbulence.

The computer circuit used to simulate these conditions is similar to the circuit for the batch-temperature transmitter and is shown in Figure 8. In this case, however, instead of being set at a fixed value, the potentiometers are made to vary automatically as a function of turbulence. This is done by using the servo-driven potentiometers of a servo multiplier whose input is a function of a selected

FIG. 7. Computer circuit for batch temperature transmitter. The τ indicates that the computer is not operating in real time—i.e., that time has been scaled. In this case time has been speeded up by a factor of 60.

FIG. 8. Circuit for jacket-water temperature transmitter. Temperature input is via a scaling pot varied by valve turbulence. Turbulence servo-feedback pot arm is loaded to proper nonlinearity.





turbulence factor. This factor is found by adding the effects of steam and water flow into the jacket, assuming that 20-percent steam flow alone produces maximum turbulence (giving a thermo-well time constant of 4 sec).

Controllers

The primary and secondary loop controllers used to control the process temperature are pneumatic stack-type industrial controllers. Two-mode pneumatic controllers provide an output proportional to the difference between the set-point and the measured variable (the error), and proportional to the time integral of the error. In equation form, the output can be written as a function of time:

$$P_o(t) = K_o\epsilon + \frac{K_o}{\tau_c}\int \epsilon dt \qquad (7)$$

Where

P_o = controller output
K_o = controller gain
ϵ = error difference between desired and actual output
τ_c = reset time constant

In Laplace notation:

$$P_o(s) = K_c\epsilon + \frac{K_c}{\tau_c s}\epsilon \qquad (8)$$

The computer circuit is easily obtained by summing the two terms as shown in Figure 9.

FIG. 9. Circuit for simulating theoretical two-mode controller.

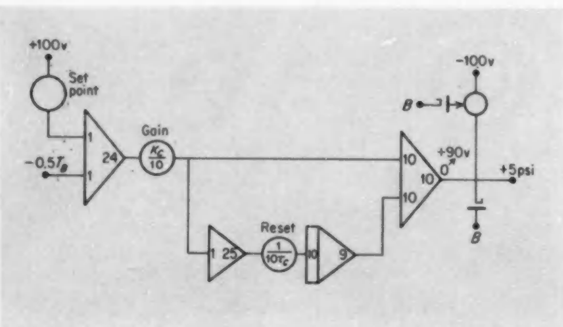
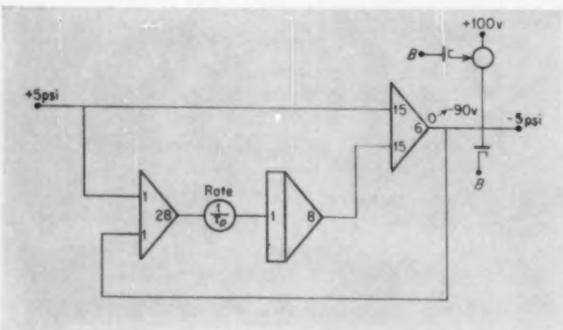


FIG. 10. Circuit for compensated derivative controller.



By definition, the transfer function of the compensated derivative mode of control is:

$$\frac{P_o}{P_i}(s) = \frac{\tau_d s + 1}{\alpha\tau_d s + 1} \qquad (9)$$

Where

P_o = output pressure of derivative controller
P_i = measured process variable
τ_d = derivative time constant
α = compensating gain — 1/15

Solving this equation for the output pressure gives:

$$P_o(s) = \frac{P_i}{\alpha} + \frac{1}{s}\times\left[\frac{P_i - P_o}{\alpha\tau_d}\right]$$

The computer circuit for solving this equation is shown in Figure 10. In order to prevent the voltage simulation from exceeding the maximum output of the controllers, diodes are added.

Ratio relay

Neglecting the dynamic characteristics of the ratio relay, this device is simulated merely as an attenuator with a value of 0.65. Thus, the set-point for the secondary controller is held at a maximum desirable temperature during start-up and maximum output from the primary controller.

Computer operation

The computation procedure consists of combining all computer diagrams into a complete circuit by connecting related variables. From this diagram the computer pre-patched panel is prepared by making patchcord connections between the various amplifiers, multipliers, and attenuators. The patch panel is then inserted into the computer console patchbay, and the reference voltage is turned on. The values of the various coefficient potentiometers are then set with the aid of the digital voltmeter. By placing the programmed patch panel in the patchbay before the potentiometers are adjusted, any possible error due to imperfect loading can be avoided.

The first step in the computation usually is to check the operation of the various components in the system. For instance, a known flow rate of steam is introduced into the circuit and the resultant process temperature is monitored to check this part of the circuit. The circuits for the valves and controllers are also isolated and checked both dynamically and statically for ranges and accuracy. Once all components have been checked individually, the system can be reconnected and the computation can begin.

It is best to establish the validity of the simulation by making a series of check solutions. A check solution establishes the fact that the simulation operates similarly to the existing system or else agrees closely with steady-state calculations. Once this is established, the investigation of the system-design changes for satisfactory performance can be made with complete confidence.

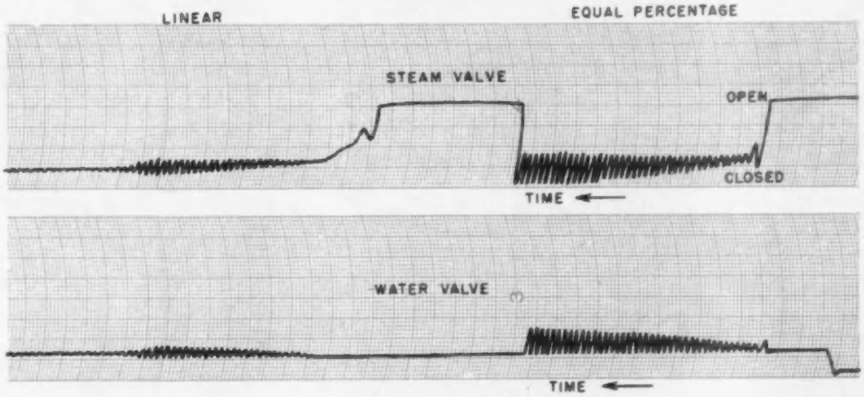
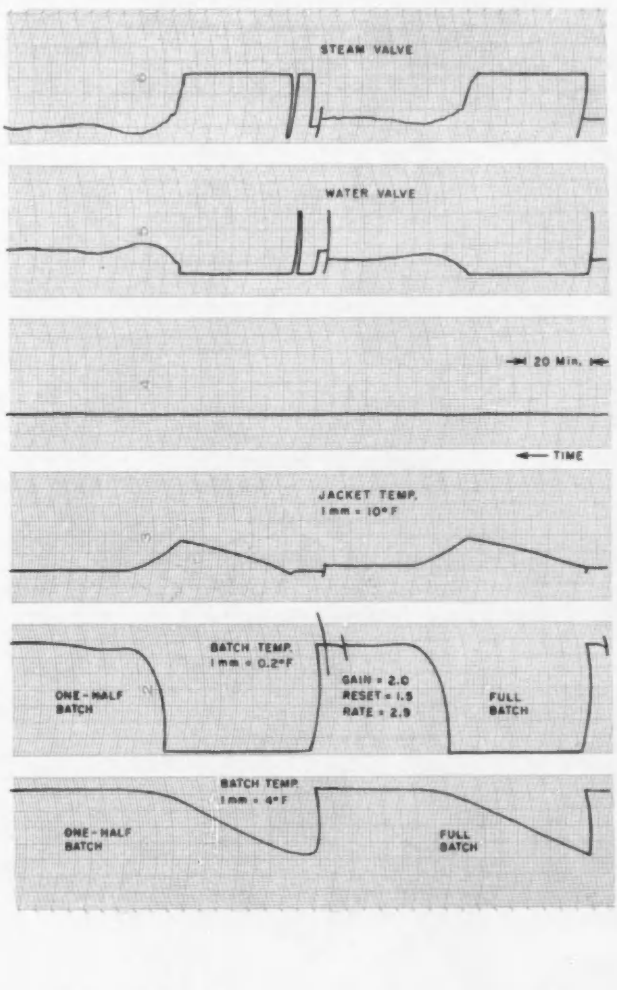


FIG. 11. Instability due to nonoptimum controller settings at first indicated linear valve trim was better than equal percentage trim; this was later disproved. Note that in all recorder charts time increases from right to left.

FIG. 12. Effect of change in batch size from full to one-half. T_b remained within 0.4 deg F.



THE RESULTS

During this simulation several runs were made, varying many of the parameters. The output of the computer was recorded and a record kept of each change. Changes which would have taken months in the field were completed in seconds with the computer. In addition, data were obtained in a form which was readily understood without any compromise in conditions such as can occur in field tests.

The results of the computation are shown in Figures 11 to 16. Note particularly that the curves advance from right to left with increasing time. Channels 5 and 6 show the movement of the valves. Channels 1 and 2 show the batch temperature—that in channel 2 being expanded in scale. Channel 3 shows the jacket temperature T_w.

By using the computer for this problem, at least one man-month of an engineer's time was saved. In addition, much equipment that otherwise would have been purchased was not required. The best control system for the process was derived and a better knowledge of the influence of varying parameters and the areas of critical adjustments was obtained.

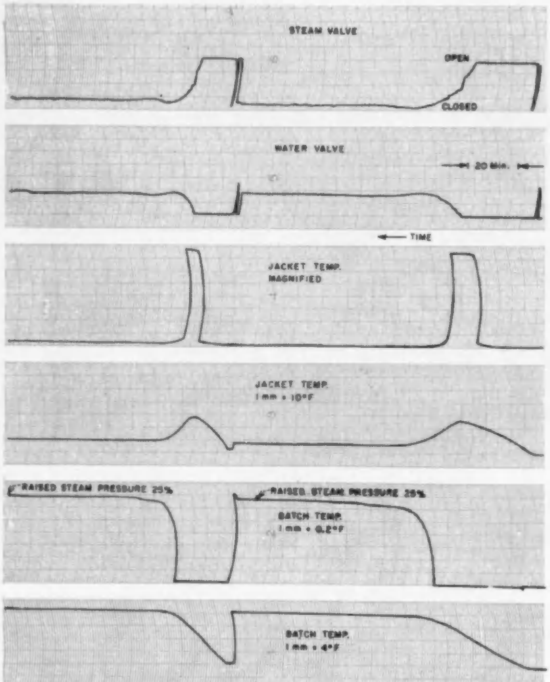


FIG. 13. Sudden 25-percent increase in steam pressure had no effect on cascade temperature control. Single-loop system showed a disturbance of more than 1 deg F.

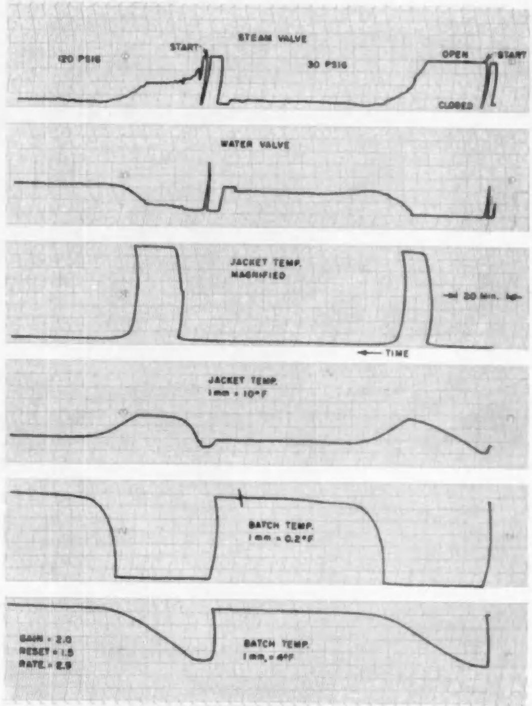


FIG. 14. A 400-percent increase in steam flow also shows favorable results. Single-loop system showed 5-deg-F overshoot and considerable valve cycling.

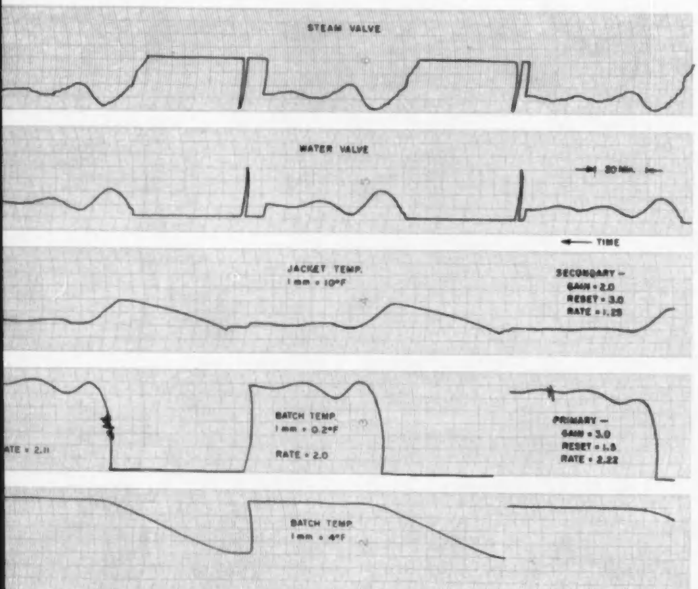


FIG. 15. Rate adjustment on primary controller proved critical. Existing controllers do not provide the precision of rate adjustment needed for this control application. Controller rate action would have to be stabilized against drift.

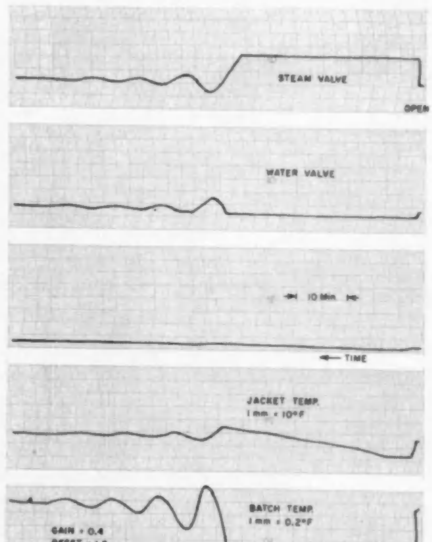


FIG. 16. Best response for any setting of single-loop controller was relatively poor. Single-loop system tied primary controller directly to valves, bypassing ratio relay and secondary controller.

Nuclear Magnetic Resonance

supplies fast answers about product composition

Nuclear magnetic resonance, a relatively new branch of spectroscopy, offers substantial rewards in the analysis of solids and liquids, and can supplement data on gases obtained by other analytical techniques. Basically, NMR identifies a sample within seconds or minutes by determining the nuclear species within the sample. It does this by subjecting the sample simultaneously to a high-frequency magnetic field and a dc magnetic field so that when nuclear resonance occurs the relation of the rf oscillation frequency to the dc magnetic field strength uniquely identifies a nuclear species. When the sample contains more than one nuclear species the product can be identified by the relation of each species in a spectrum. Information appears intermittently, leading to control by sampled-data systems.

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The value of nuclear magnetic resonance (NMR) as an industrial analytical tool lies in its ability to make simple nondestructive tests specific to a particular nuclear species in either liquids or solids, and do this with a minimum of sample handling. The techniques of NMR have been successfully applied to product identification in the petroleum and chemical industries and to moisture determination in the food processing industries. In addition to these isotopic identifications, NMR studies can be related to a wide variety of physical phenomena, giving information on bond energies, crystal structure, diffusion rates, phase transitions, surface phenomena, chemical group identification, and interactions between nuclei and electrons. However, this article treats NMR primarily as a device for identifying products and determining moisture content.

The ultimate application of NMR—as a control instrument in a closed-loop production system—has not as yet been widely attempted in industry. It has been recognized, however, that the ability of NMR to provide simple, easily interpreted data within seconds or minutes does make such application an attractive possibility. Eventually, as simpler and more reliable instruments become available, NMR should become important in plant control.

THE BASICS OF NMR

The nuclei of some particular atoms have a very definite angular momentum or spin. As a result of

TABLE 1—Some of the More Common Light Nuclei Which May be Detected with NMR

Isotope	Nuclear spin	$\gamma/2\pi$* cps/gausses	χ_0**x10^{12}
$_1H^1$	1/2	4.26x10^3	50
$_1H^2$	1	0.654	3.1
$_3Li^6$	1	0.626	2.9
$_6C^{13}$	1/2	1.07	3.2
$_7N^{14}$	1	0.308	0.7
$_8O^{17}$	5/2	0.577	11
$_{11}Na^{23}$	3/2	1.13	18
$_{17}Cl^{35}$	3/2	0.417	2.4

* The oscillator frequency, at which a particular nucleus spins in a field H, is $\gamma H/2\pi$. For example, in a field of 1,000 gausses the hydrogen ($_1H^1$) resonance occurs at 4.26 mc.
** The nuclear susceptibility given here corresponds to 10^{22} nuclei per cc at room temperature. It gives a good indication of the relative sensitivity of the NMR detector for different nuclei.
(Complete NMR Table available on request from Varian Associates, Special Products Div., Palo Alto, Calif.)

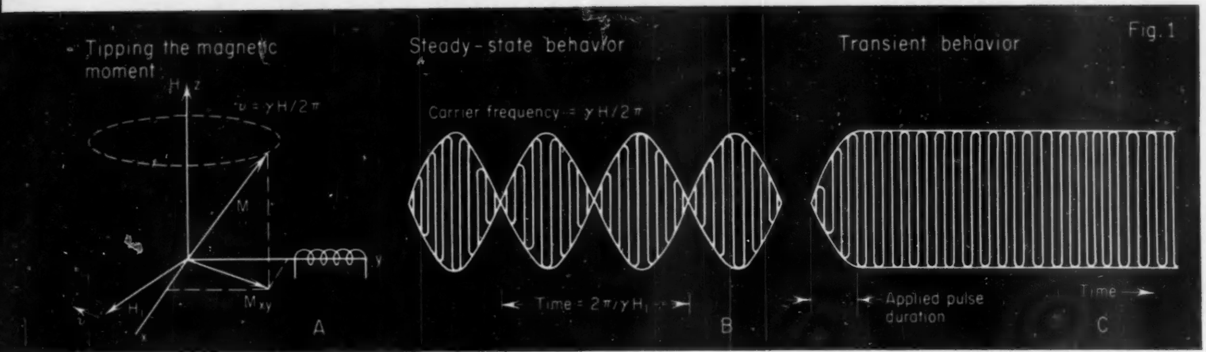


Fig. 1

this angular momentum, they also have a very definite magnetic moment. A nucleus with these properties may be thought of as being a tiny bar magnet spinning about an axis through its poles.

When such a spinning magnet is placed in a uniform magnetic field H, it becomes subjected to a torque. Because of its spin or angular momentum the particle behaves like a gyroscope. That is, the applied torque makes the particle precess around the field direction at a very definite frequency called the "Larmour frequency". The Larmour frequency, ν, is simply related to the field H by a constant $\gamma/2\pi$ characteristic of the precessing nucleus:

$$\nu = \gamma H/2\pi$$

Thus, the oscillator frequency at which a particular nucleus could be observed (resonated) in a field H is $\gamma H/2\pi$. Table 1 lists the $\gamma/2\pi$ values of some representative nuclei, together with their nuclear spin. The table shows, for example, that in a field H of 1,000 gausses the hydrogen resonance would occur at 4.26 megacycles per sec.

If a large number of magnetic moments could be observed simultaneously they would be found to make all angles with the applied field H, although a greater number of moments would have a component in the direction of H than against it. In a unit volume of material the total component of the considered moments in the direction of the applied field is the magnetic moment M. The moment M is proportional to H, the proportionality coefficient being, by definition, the nuclear magnetic susceptibility χ. Thus $M = \chi H$.

The resonance principle

The following discussion of the resonance principle is concerned chiefly with the behavior of the macroscopic moment M in the presence of a field rotating at the Larmour frequency. M is normally lined up in the applied dc field direction, but if it is tipped out of this direction it will precess around the applied field H at the Larmour frequency, as illustrated in Figure 1A. The component in the x-y plane, M_{xy}, equivalent to a small magnet rotating at a very precise frequency, induces a signal in a pickup coil surrounding the sample. The signal is a maximum when the coil axis lies in the x-y plane.

The tipping of M out of the z-direction may be accomplished very efficiently by applying an rf magnetic field H_1 perpendicular to the z-axis, which rotates about the z-axis at the same frequency and in the same sense as the precessing moments. The moments in their motion about the z-axis thus see the H_1 field as a static field and begin to precess about it also. As a result M tips further away from the z-axis. If nothing else occurred the moment M would continue to precess around H_1 with a frequency

$$\nu = \gamma H_1/2\pi$$

and the induced signal in the surrounding coil would be amplitude-modulated, as shown in Figure 1B.

If the H_1 field is applied in the form of a pulse such that the pulse length is just long enough for the moment M to rotate through 90 deg into the x-y plane the pulse is called a 90-deg pulse. The pulse duration may be determined by the relation:

$$\tau_0 = \pi/2\gamma H_1$$

In the absence of any external interaction (interaction does actually exist), the signal following the 90-deg pulse would be a nondecaying sine wave at the Larmour frequency, as shown in Figure 1C, and since it is now in the x-y plane (as is the pickup coil) M induces the strongest signal in the coil.

The rotating field H_1 is difficult to obtain in practice, but Figure 2 shows that such a field could be obtained from a linearly oscillating field by considering the linear field as being made up of two fields rotating in opposite sense from each other. Only that part of the linear

Obtaining a linear oscillating field

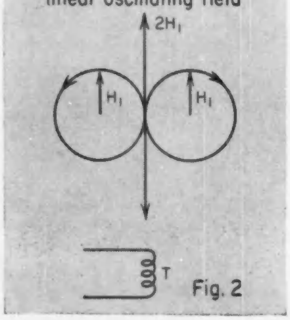


Fig. 2

field rotating in the same sense as the precessing nucleus contributes to the resonance phenomenon.

Relaxation times in NMR

So far only the interaction of the nuclear moments with the applied field has been considered. In any real system, however, these moments will also interact with each other and with their environment, which, for convenience, is usually called the "lattice". These interactions cause system damping, and the system then returns to equilibrium after a certain time. The signals described in Figures 1B and 1C thus actually die out (approximately) exponentially. To specify these interactions in terms of measurable quantities two relaxation times, the spin-lattice relaxation time T_1 and the spin-spin relaxation time T_2, are defined.

When the system of nuclei is placed in a field H, the full moment M does not appear immediately, but builds up exponentially.

$$M = \chi H(1 - e^{-t/T_1}) \qquad (7)$$

to its final value χH. Thus the spin-lattice time T_1 characterizes the buildup, and as such is a measure of the rate at which the nuclear spin system exchanges energy with the lattice.

An assumption has been made that following a 90-deg pulse the moment M continues to precess in the x-y plane for an indefinite time. Actually, the interaction of the neighboring nuclei causes the individual moments to get out of phase with one another and with the macroscopic moment, with the result that M fans out in the x-y plane. The total component M_{xy} in any one direction is then found to decay exponentially

$$M_{xy} = Me^{-t/T_2} \qquad (8)$$

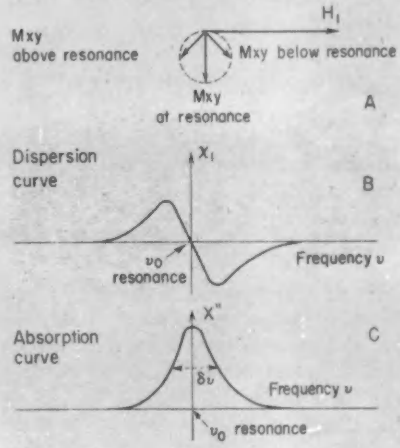
with a time constant T_2. Thus the spin-spin relaxation time T_2 is a measure of the rate at which the nuclear moments transfer energy to one another either directly or through the lattice. As a result T_2 may be smaller than T_1, but never larger. Table 2 shows the relaxation times for protons for some representative materials. T_1 varies from microseconds to days, depending on the substance being investigated. T_2 is usually found to be fairly large in liquids and quite small in solids. In nonviscous liquids T_1 and T_2 are usually equal, while in solids T_1 may be quite large and T_2 quite small.

The relaxation times play an important role in the detection of the NMR signal and they must be considered in choosing the sweep rates and time constants of the detecting instruments.

TABLE 2—Relaxation Times of Hydrogen Nuclei (Protons) in Various Materials

Substance	T_1 in sec	T_2 in sec
Water (23° C)	2.73	2.73
Ice (−10° C)	3.0	10^{-5}
Benzene (23° C free of O_2)	18	18
Corn Syrup (23° C)	4×10^{-2}	6×10^{-3}

Fig. 3
Nuclear susceptibility about resonance



Steady-state behavior

Suppose a small applied rotating field H_1 is utilized such that the relaxation time T_2 is much less than the period $2\pi/\gamma H_1$ of the precession around H_1. Then when the magnetic moment is tipped out of the z-axis it immediately begins to fan out at a rate determined by T_2 and the moment is lost before it has rotated through any appreciable angle. Under these conditions a macroscopic dynamic equilibrium is established between the tipping action of H_1, the fanning out of M_{xy} at a rate determined by T_2, and the building up of the z-component of the magnetic moment at a rate determined by T_1. In this equilibrium the magnetic moment has a constant component on the z-axis and a rotating component M_{xy} in the x-y plane with a constant amplitude and a constant phase relationship with respect to H_1. This M_{xy} component is capable of inducing a steady signal in the surrounding receiver coil, and the signal lasts as long as the field H_1 is applied.

The M_{xy} component, rotating at the same frequency as H_1, exists even if the field H_1 is not rotating at exactly the precession frequency of the nuclei in the dc field H. But its amplitude and phase with respect to H_1 depend on the difference between the frequency of the field H_1 and the precession frequency. Figure 3 shows the relative disposition of the M_{xy} component of the macroscopic nuclear magnetic moment perpendicular to the dc field with respect to the rotating rf field H_1. The vector diagram indicates that at resonance M_{xy} lags the field by $\pi/2$ radians, and that the lag reduces to zero when the rf frequency decreases below the resonance frequency, and increases to π when the frequency goes above resonance. Figure 3A then suggests the definition of a complex rf magnetic susceptibility relating M_{xy} to H_1:

$$M_{xy} = (\chi' - j\chi'')H_1$$

where $\chi'' H_1$ is the out-of-phase component of M_{xy} with respect to H_1 and $\chi' H_1$ is the in-phase component. Figures 3B and 3C give typical shapes of curves of χ'' and χ' vs. frequency. Figure 3B is called a dis-

persion curve and Figure 3C is called an absorption curve.

Line width, a term often used in NMR, is defined on the absorption curve as the width at half the peak amplitude. It is expressed in units of frequency or of field strength, and is related to the relaxation time T_2 by:

$$\delta\nu = \gamma\,\delta H/2\pi = 1/\pi T_2$$

It may be shown that the rf magnetic susceptibility, which is independent of H_1 for small values of H_1, decreases to zero when H_1 increases indefinitely and the phenomenon is known as saturation of the system of nuclei by the rf field. The condition that the rf susceptibility be independent of H_1 is:

$$\gamma^2 H_1^2 T_1 T_2 << 1$$

HOW NMR EQUIPMENT WORKS

The two classes of NMR equipment are based upon different approaches to detecting NMR phenomenon. The first class makes use of the transient method—the system is first taken away from its equilibrium and then observed as it returns freely to equilibrium. The apparatus for detecting transient NMR signals is complicated and (as far as is known) not commercially available. The transient method will not be discussed further in this article.

The second class of NMR equipment makes use of the steady-state method—the system of nuclei is kept in a condition of dynamic macroscopic equilibrium. The sample is placed in a dc magnetic field and the nuclei are continuously excited by a weak rotating rf magnetic field perpendicular to the dc field. The macroscopic magnetic moment then has a definite component in the plane perpendicular to the dc field, and the component rotates around the dc field at the frequency of the applied rf field—not necessarily at the precession frequency of the nuclei. This phenomenon is one essentially of forced oscillations—resonance occurs when the frequency of the applied rf field equals the precession frequency of the sample nuclei within the applied dc magnetic field.

The rotating component of the macroscopic nuclear magnetic moment induces a signal at the corresponding frequency in a coil which surrounds the sample with its axis perpendicular to the dc field. The NMR detector measures this signal and, in most cases, records signal variations as the field is swept through resonance to indicate the nuclei present in the sample.

The steady-state NMR method is somewhat analogous to the one used in the study of the resonance curve of a tank circuit excited by a sinusoidal signal. In NMR the resonance frequency of the system is determined by the strength of the dc magnetic field, much the same as the resonance frequency of the tank circuit is determined by the value of its inductance and capacitance. The behavior in the neighborhood of resonance can be investigated by sweeping either the frequency of the exciting rf magnetic field or the strength of the dc magnetic field. In most cases it has been found more practical to sweep the dc magnetic field.

Basic NMR components

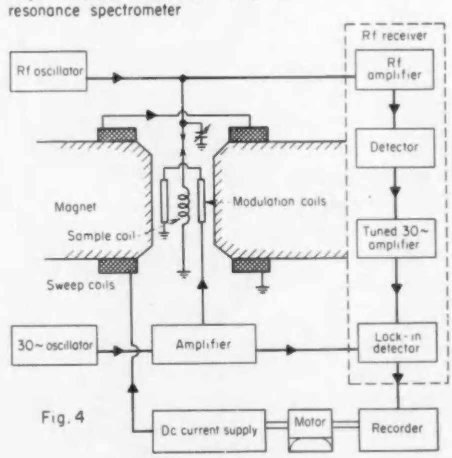
Although there are several types within the steady-state class of NMR apparatus, only one will be described, and this in terms of the functions of the major components. Figure 4 is the block diagram of a simple NMR apparatus.

In Figure 4, the source of the dc magnetic field H is a permanent magnet. This provides, in a gap between two precisely flat and parallel pole pieces, the very uniform field the apparatus requires to assure that every part of the sample resonates at the same time during the sweep of the field. A set of coils, wound around the permanent magnet, sweeps the field strength over a limited range (in the order of 50 milligausses in a nominal strength of 1,000 gausses) by adjusting the current in the coils.

The rf magnetic field H_1 comes from a coil in which rf current circulates. The coil constitutes the main part of the probe assembly and is placed in the center of the gap with its axis perpendicular to the dc magnetic field. The sample occupies the inside of the coil. A stable oscillator (generally crystal-controlled) feeds the rf coil at the proper frequency. For common field strengths of 1,000 to 10,000 gausses the resonance frequency for nuclei is between 100 kc and 50 Mc.

In the arrangement shown here the sample coil serves as both the rf field coil and the receiver coil. The processing nuclei induce a weak voltage superimposed on the rf voltage. The resulting signal then shows up as an amplitude variation of this voltage. Generally, the coil is tuned to the frequency of the signal to increase (multiply) the weak signal voltage by the Q of the coil. The coil voltage is then ampli-

Major components of nuclear magnetic resonance spectrometer



fied and detected. The output of the detector, which is the signal due to the precessing nuclei, is recorded against the sweep of the dc field. The resulting record is the absorption curve, Figure 3C.

Sometimes the amplitude variations due to the precessing nuclei are so small that the detection system requires a very narrow effective bandwidth to reduce the noise level. The field strength of the sweep coils must then be varied slowly through resonance and a low-pass filter must be placed between the detector output and the recorder. But a slow dc drift, independent of the NMR signal, will not be distinguishable from the true NMR signal. To avoid any error here, a small periodic modulation, of constant amplitude and low frequency, is superimposed on the swept dc field, Figure 5A. This field modulation modulates, at the same low frequency, the NMR signal superimposed on the rf coil voltage. After detection of the rf signal only the component of the signal at the low modulation frequency is amplified in a tuned audio amplifier and then demodulated in phase with the applied modulation. The resulting signal then goes through a low-pass filter and is recorded. The recorded curve is, for small modulation amplitude, proportional to the derivative of the absorption curve, Figure 5B.

NMR equipment variations

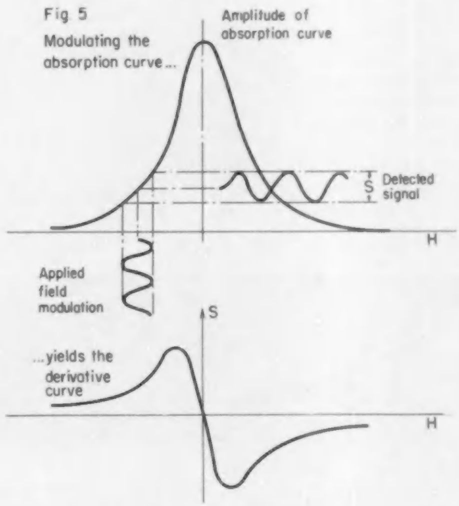
The most common variations of the NMR apparatus described are:

- using an electromagnet instead of a permanent magnet as a source of dc magnetic field. This gives more flexibility for varying the normal field strength over a very wide range.
- using a separate receiver coil in a position of minimum coupling (absolutely no coupling is difficult to obtain) with the rf exciting coil. This residual coupling is small and may be adjusted in phase.
- using the rf amplifier as the oscillator to create the rf magnetic field—the NMR signal thus varies the oscillation amplitude. This type gives more flexibility for adjusting the rf field frequency simply by tuning the tank circuit.

NMR resolution

The resonance-curve shape obtained from a given nuclear species is characteristic of the physical state of the sample. The resonance curve may be a single bell-shaped line or it may be a composite of several lines corresponding to the number of substates available to the nuclei.

The width of the line or lines (width of the absorption curve at half-amplitude) may be expressed in magnetic field strength units. To record actual line shapes the dc magnetic field must be more uniform (over the volume of the sample) than the width of the narrowest line to be observed. Otherwise distortion of line shapes occur and the lines may run together and appear as a single line trace on the recorder. Also, the detection apparatus can distort



the line shapes if its various parameters are not kept within the limits dictated by the sample's relaxation times.

In general, liquids produce very narrow resonance lines in the order of milligausses, while solids produce line widths in the order of several gausses. As a result, a specific apparatus is usually limited to observations in a certain range of sample line widths, the chief limitation being the uniformity of the dc magnetic field over the sample. Therefore NMR apparatus is customarily classified in terms of its ability to resolve a line of a certain width. The resolution is expressed as the maximum inhomogeneity in percent of the dc field strength over the volume of the sample. A high resolution apparatus has a magnet inhomogeneity of one part in 10^6 to 10^8, a low resolution a magnet inhomogeneity of one part in 10^5 to 10^6. Of course the volume of the sample is not the same in all cases; for high resolution the sample volume is usually about a tenth of a cc or less, and for low resolution it is as much as 50 cc. Thus liquids, with narrow lines, require high-resolution apparatus while solids, with wider lines, can use low-resolution apparatus.

ANALYSIS WITH NMR

Single-line spectra

One obvious application of NMR is the identification of isotopes by finding the characteristic $\gamma/2\pi$ of the sample nuclei. That is, the oscillator frequency and dc field strength required to make the precession frequency resonate determine the characteristic $\gamma/2\pi$ of the sample nuclei, from Equation 1. Identification occurs by comparing $\gamma/2\pi$ with a table of nuclear moments, such as Table 1.

The study of line width and relaxation times as a function of temperature often provides information useful in the studies of phase transitions and molecular motion. The typical behavior of the proton line width in a polymer as a function of temperature,

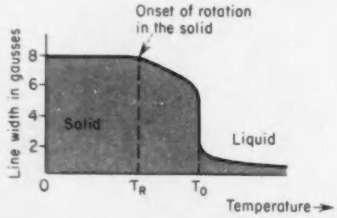


FIG. 6. This plot of line width vs. temperature for a polymer often yields considerable information about the internal molecular motion. Line width in the liquid phase is a measure of viscosity, thus indicating the use of NMR as a viscometer.

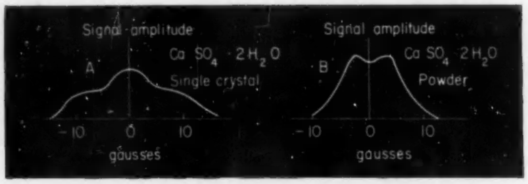


FIG. 7. A single crystal of gypsum in a given orientation yields one absorption curve (A), while the same material in powder form yields a different absorption curve (B). The two shapes result from the directional character of the interaction of a water proton with its neighbors.

Figure 6, is an example. The interaction of the neighboring magnetic moments determines the line width in the solid. The onset of rotational and finally translational motion as sample temperature increases causes the dipole interaction to be averaged out and the line narrows.

The change in the line width with changes in molecular motion is the basis for the application of nuclear magnetic resonance to the study of liquids and gases bound to solid surfaces. The resonance lines of nuclei in fluids tightly bound to a surface are fairly broad while the lines of nuclei in free liquids are comparatively narrow.

Multiple-line spectra

The NMR line width may be thought of as arising from small local fields contributing to the applied field at the site of the resonating nuclei. In general, these local fields are random and the line shape is determined by the statistical distribution about zero. In some cases, however, the local fields have very definite values and more than one line appears in the resonance.

Discrete values of local fields may be found in solids where a given nucleus has only a limited number of neighboring magnetic nuclei with which it can interact. Such a situation arises in gypsum, where the only effective local field a proton in a molecule of water of hydration sees is the dipole field due to the other proton in the same molecule. Analysis of NMR spectrum in these cases determines the orientation and separation of nuclear pairs and triplets in crystals[1]. Figure 7 shows typical absorption curves obtained from a single crystal and a powder sample of gypsum.

If the NMR spectrum of nuclei in liquids is examined in a very homogeneous field it is found to be made up of a number of resonance lines spaced very closely together. This structure may be attributed to two phenomena affecting the local field at the nuclei. These are chemical shift and electron-coupled spin-spin interactions. To observe the structure, the line width as well as the sample field inhomogeneity must be less than the separation of the resonance lines to be resolved.

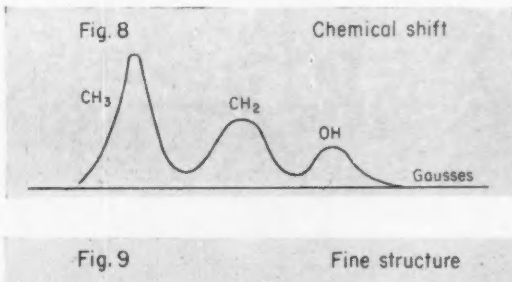
As was mentioned previously, the sweep rates used in the presentation of the resonance must be determined by the relaxation times. In liquids with very long relaxation times (narrow lines) therefore it is necessary to sweep through the resonance very slowly and in general the narrower the resonance line to be observed, the more slowly the field must be swept through the line. This criterion sets the specifications on the stability of the circuit components of high resolution NMR equipment.

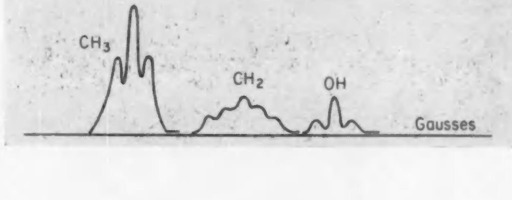
Chemical shifts

Changes in the local diamagnetic field produced by valence bonds cause chemical shift. The valence bonds distort the electron symmetry about the nucleus, the amount of distortion being determined by the particular chemical group. The classic example of chemical shift is the proton resonance in ethyl alcohol, Figure 8. Here, three lines correspond to the three groups of protons CH_3, CH_2 and OH. The signal peak heights are in the ratio 3, 2, and 1. Chemical shifts are proportional to the applied field H—for protons the field inhomogeneity over the sample should be better than one part in $10^6 H$. The ability to identify proton groups in complex molecules, especially complex organic molecules, makes NMR a very useful tool for the analytical chemist, and chemical shift analysis is already finding application in control laboratories.

Fine structure

Nuclei which do not have the same Larmour frequency in a given field are found to interact with each other over considerable distances through the spins of valence electrons. This effect occurs not





only for different nuclei but also for nuclei in different chemically-shifted groups. If a very pure sample of ethyl alcohol is placed in a field of higher homogeneity than used to produce the trace in Figure 8, a trace like the one shown in Figure 9 results. Interestingly enough, the trace of the *OH* radical in Figure 9 reverts back to the single-line shape of Figure 8 when H^+ or OH^- ions in such small concentration as 10^{-5} normal are added to the sample. The practical implication of this statement is that minute amounts of water can be detected in pure alcohol by observing whether OH^- proton resonance shows structure or is a single line, and this information can be obtained nondestructively in a few minutes with NMR equipment.

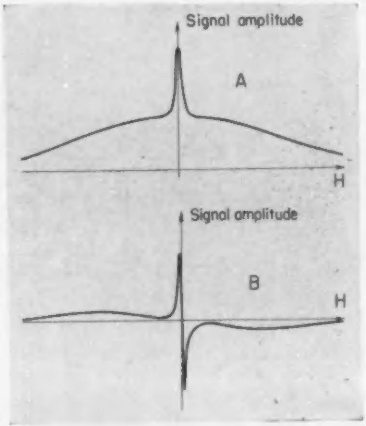


FIG. 10. The absorption curve (A) obtained from moist starch shows the water signal sitting on top of the starch signal. Use of a modulation yields the derivative curve (B), where the peak-to-peak amplitude of the narrow line indicates the moisture present in the sample.

APPLYING NMR IN INDUSTRY

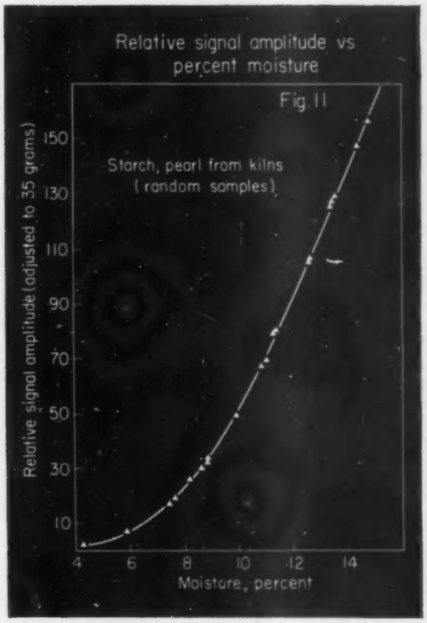
Data obtained from an NMR spectrometer take a variety of forms, ranging from an accurate count of the gross number of a particular species in a sample to records which yield, with proper interpretation, subtle information relating to molecular structure. It is not difficult to imagine an application of high-resolution NMR to periodically monitor the yield of a reaction, such as aromatization, by observing the spectra. Of much broader potential for industry is the accurate and speedy measurement of water—particularly in granular solids, where other physical methods have severe limitations—since hydrogen has the highest sensitivity of any nuclear species to detection by NMR.

Measuring moisture content in starch

NMR techniques have been applied to the measurement of the amount of moisture in starch. The NMR signal indicates the quantity of protons, of which there are two types in the moist starch: the ones in the starch (a carbohydrate) and the ones in the water adsorbed on the starch. The starch protons record as a very broad line, since the starch is a solid, of about 5 to 10 gausses, whereas the water protons yield a much narrower line. Actually, the width of the water line depends on the moisture content and varies from about 100 milligausses for 15-percent moisture content to about 500 milligausses for 4-percent moisture content. In all cases the water proton line is much narrower than the starch proton line, and they are easy to distinguish from each other—as seen in Figure 10A.

The narrow line from the water sits on top of the broad line from the starch. In Figure 10A the weak signal requires the use of the modulation technique, mentioned previously, to bring out the derivative of the absorption curve, Figure 10B. The peak-to-peak amplitude of the derivative of the narrow curve is not usually affected by the broad line, which has a zero derivative wherever the signal from water has an appreciable amplitude.

Experimental results show a good correlation between the peak-to-peak amplitude of the derivative



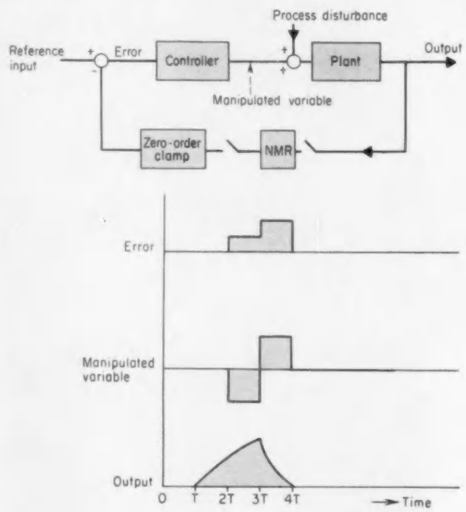
of the narrow absorption curve and the moisture content of the starch sample as determined by the regular method of drying the sample in an oven. The calibration curve, Figure 11, is not a straight line because of the variation of line width with the moisture content and the possible variation in the bound-water-to-free-water ratio with moisture content.

This calibration curve has been obtained by the Corn Products Refining Co. along with many other curves referring to their various products. The authors wish to acknowledge here the very important work done by that company in the evaluation of the NMR technique for moisture determination, and to thank them for allowing publication of the calibration curve.

Closing the loop with NMR

NMR apparatus resembles an increasing number of industrial analytical instruments, such as vapor-

Plant control using sampled NMR directly Fig. 12



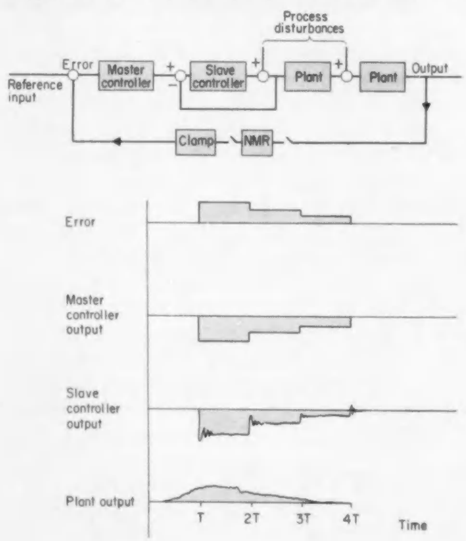
phase chromatographs and mass spectrometers, in their inherently data-sampling nature. Data are read out at periodic intervals, and the basic measure of the response speed is the sampling period T, which may be between a fraction of a second and several minutes depending on the spectral response of the material. The materials handling system itself introduces a significant transportation, or distance velocity, lag.

A characteristic of sampled-data systems, distinguishing them most markedly from continuous-control systems, is that most of the time the system operates under open-loop conditions[7]. Information is available to the controller only at the instant of data-sampling and anything that happens between data samples is not discovered and cannot be corrected until the next sampling instant.

The sampling period T, or rather the ratio of this period to the time constants of the plant to be controlled, strongly influences the performance of the sampled-data control system. When T becomes very much smaller than the plant lags, the system behaves as though the data were continuously available to the controller. When T is much larger than the plant lags, the system, under open-loop conditions most of the time, cannot perform as well as truly continuous control in correcting for disturbances. When T is of the same order of magnitude as the plant lag, the system designer has the most flexibility at his disposal: in fact, here a simple sampled-data controller may control many times better than does continuous control[9].

The controller must be designed very carefully, particularly if the sampled analytical information controls the process directly, Figure 12. A suitable controller program makes sure that recovery from a disturbance is optimum, i.e., transient duration is brought to a minimum by using the full corrective action available [7, 9]. However, there is then some risk that performance will deteriorate when process parameters change, (for example, with load changes).

Fig. 13 Plant control combining sampled NMR with cascade control



NMR with cascade control

In other practical applications the processing conditions will be well controlled by regular continuous process-control equipment. Then the sampled analytical information trims the set-points of one or more process controllers. Figure 13 shows a cascade-control arrangement where the master controller acts intermittently on its slave or slaves.

General principles and design methods of cascade-control systems have been described in the literature (References 10-13). Basically, it can be shown that in continuous control the application of cascade control is equivalent to introducing a phase lead approaching 90 deg, which leads to a corresponding improvement in system controllability. In systems where the primary data are sampled, the design requires more than usual care. At each sampling interval the output from the master controller is equivalent to a step change of reference input (set-point) to the slave controller. Inevitably, a transient in the second measured variable follows each such step input. If the (linear) slave controller is adjusted for minimum deviation following a process disturbance, with semi-oscillatory decay, some overshoot occurs when a step change of input is applied, Figure 13. The sampling period T must be long enough to allow equilibrium in the subsidiary loop to be attained before the next data sample is taken.

NMR controls driers

The continuous-circulation drier with variable air recirculation, shown in Figure 14, poses some complex system design problems, since the percentage of moisture in the dried product is a function of a number of possible manipulated variables. For simplicity, it is assumed here that a moisture measurement requiring a minimum of interpretation is made periodically using NMR, and that the drier tunnel, where product moisture control is carried out, consists of only one segment.

In this plant arrangement the product becomes drier when: belt speed decreases, feed rate decreases, feed moisture decreases (principal disturbance), or steam-to-heat exchanger increases.

The dynamic effects of each of these variables on product moisture content vary considerably. Product dryness is not, in general, uniquely dependent on vent flow rate: when vent flow is a small percentage of the recirculation flow an increase in vent flow decreases the moisture content by decreasing the humidity of the air in circulation, but when vent flow is larger than recirculation flow, an increase in vent flow increases product moisture content by reducing the recirculating air velocity.

The system arrangement of Figure 14 (one of several possibilities), in which the NMR output is applied to the vent flow controller, is therefore operable within limits determined by plant design. The air-flow control loop will have time constants in the order of seconds. Time constants relating air flow to product moisture content will be of the order of minutes—comparable to or larger than the transportation lag in sample-handling and the data-sampling period. Consequently, the system requires careful design and may even require a sampled-data computer interposed between the NMR instrument and the process controllers.

Dynamically, this system is more complicated than it looks: an increase in feed moisture increases product moisture before the wetter segment of the feed reaches the end of the belt because it causes a rapid increase in recirculated-air humidity. Similarly, an increase of load causes a relatively rapid increase in product moisture. Under some operating conditions supplementary feed-forward controls linking feed rate and/or belt rate to steam flow and vent flow may be necessary to achieve satisfactory results and optimize drier efficiency.

Flash and spray driers are so constructed that the residence-time of material being dried is only a few seconds. The process time-constants are therefore seconds or fractions of a second and are usually shorter than the data-sampling period. In this type drier the product temperature is normally controlled by manipulation of wet feed flow or heat supply. Since the sampling period and material-handling lag will be large compared with the process time-constants, a cascade control system will be necessary to minimize the effect of disturbances such as changes of feed moisture content, which may occur rather rapidly. The system will then behave as shown on Figure 13, where the slave controller controls the product temperature. The NMR moisture controller can trim the set-point of the temperature controller as required, and the temperature controller does most of the "work", in the sense of correcting rapid transient upsets. Special controller design is probably unnecessary in most such industrial applications.

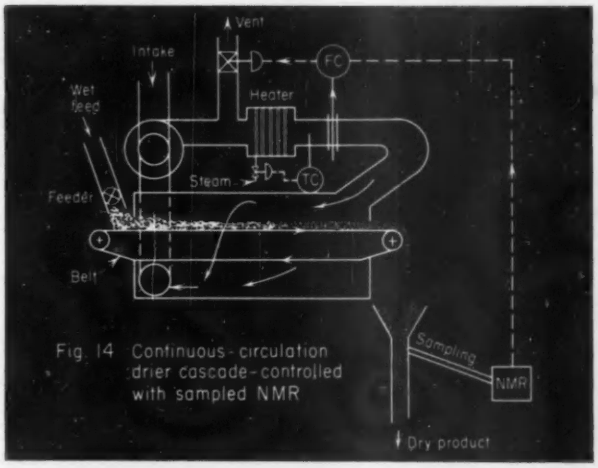


Fig. 14 Continuous-circulation drier cascade-controlled with sampled NMR

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Interpolating Point-to-Point Inputs for Continuous Machine Control

Making cam gears on an automatic gear shaper involves the control of two machine motions as nonlinear functions of cutter rotation. Since the control cycle is continuous for periods of 12 min or more, the machine might rightly be expected to devour reams of recorded information. However, through a unique and relatively simple mechanization of the Gregory-Newton interpolation formula, all necessary data have been squeezed into just 27 lines of a card.

JACK SPELLER, Norden Lab. Div., Norden-Ketay Corp. and JOHN D. COONEY, Control Engineering

Although nonlinear (cam-shaped) gears offer intriguing possibilities in machine and control design, actual applications are virtually nonexistent. The reason is that until recently there was no practical method for making such gears. The automatic shaper for producing circular gears has been a reality for years, but enormous control problems blocked its adaptation to cam-gear manufacture. It remained for a vital need for a source of cam gears to spur a control firm into making this adaptation*.

The cam gears were needed for an instrument developed by Norden Laboratories Div. of Norden-Ketay Corp. to measure airplane speed in terms of Mach number. A problem in the design was the conversion of a θ input into a tan θ output. This could have been done by means of nonlinear potentiometers, by electronic circuitry, or by a pair of tangent gears, Figure 1. The last was seen to accomplish the computation most simply and with high accuracy, and so their manufacture was undertaken by Norden engineers.

Their gear-making equipment, Figure 2, consists of a modified Fellows gear-shaper and two cabinets of control apparatus. The machine shown automatically produces tangent gears of instrument quality at a rate of 10 every 12 min. Control input is numerical, in the form of a binary code inscribed on a printed-circuit board. Individual boards can be

* An earlier approach to the automatic cam-gear production is described in "Controlling Machine Tools Automatically" by Frederick W. Cunningham, "Mechanical Engineering," June 1954, pp 487-490.

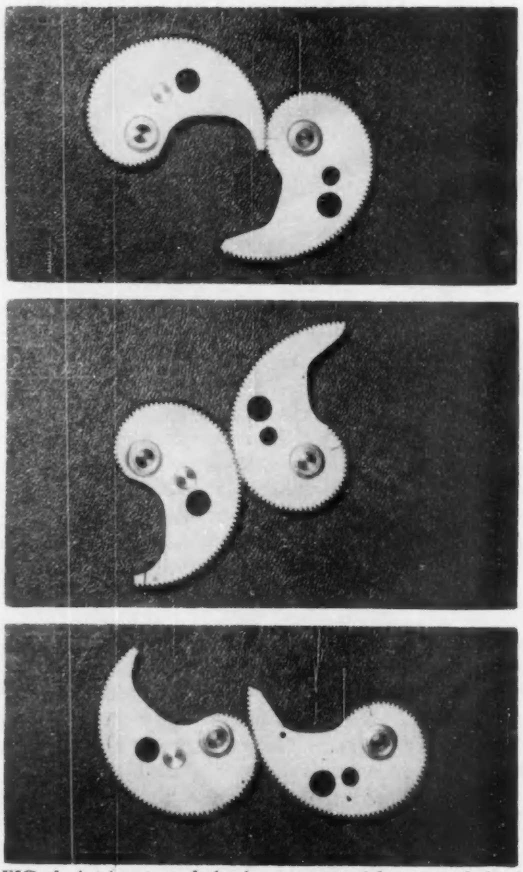


FIG. 1 A θ input on shaft of cam gear at right causes shaft of second gear to rotate through tan θ. In sequence, pictures A, B, and C show start, middle, and end of function generation.

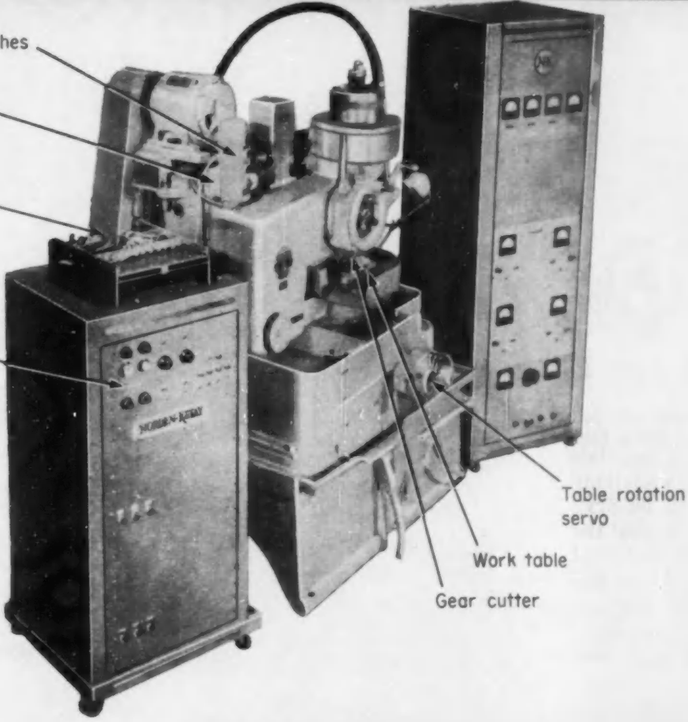


FIG. 2. Machine tool and control equipment for producing cam gears. Cabinet at left contains circuits for generating nonlinear control signals. Power supplies and servo amplifiers are in second cabinet.

prepared to generate nonlinear gear configuration within the dimensional limits of the machine.

Machine Description

In the conventional circular-gear shaper, the gear blank is mounted horizontally on a worktable and the cutting tool is reciprocated vertically in contact with the periphery of the blank. Gear teeth in the cutter generate similar teeth on the blank. At the start of a run, the cutter is fed radially into the blank until full tooth depth is reached. Then the reciprocating cutting action is continued while the cutter and the blank are slowly rotated about their axes at the same peripheral speed. These operations proceed until all teeth have been formed into the blank, after which the cutter is backed away.

Now, the basic problem in converting the machine for making cam gears can be appreciated. The reciprocating cutter may still be rotated at some constant speed, but the center-to-center distance between cutter and blank must be varied continuously as some nonlinear function of cutter rotation. And, to maintain the constant peripheral speed relationship between cutter and blank, worktable speed must be varied continuously as a nonlinear function of cutter rotation.

The mechanical modifications needed to accomplish the necessary nonlinear movements were comparatively elementary. First, a servomotor drive plus a 15-turn feedback pot, Figure 3, were installed to control the cam that moves the cutting tool radially toward and away from the axis of the blank. Second, a servomotor-potentiometer arrangement, Figure 4, was substituted for the standard worktable drive. By supplying the proper nonlinear dc voltage signals to

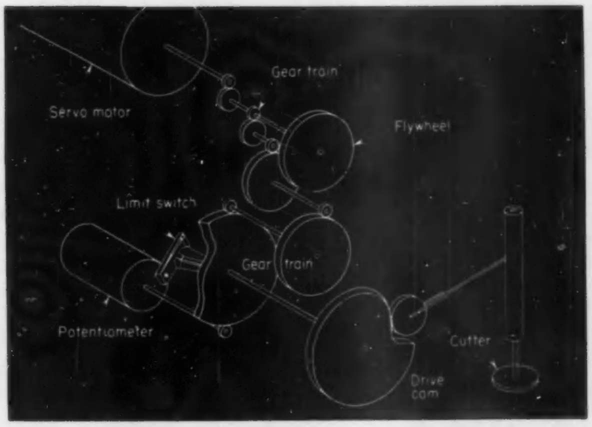
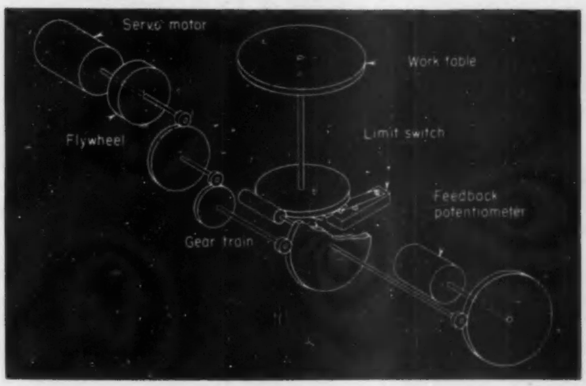


FIG. 3. Mechanism for adjusting center-to-center distance between cutter and worktable.

FIG. 4. Servomotor drive for controlling worktable speed as function of cutter rotation.



the drive servos, both worktable and tool slide could be moved as a function of cutter rotation so as to generate any configuration of cam gear.

The major design problem was to devise a means for translating the gear contours into analog voltage information that could control the servomotors.

Ordinate Data

An elementary form of the nonlinear relationship between cutter-gear rotation (or angular position) and tool-slide position is shown in Figure 5A. Only this relationship and the details of tool-slide control will be described here. It should be noted, however, that the discussion of operation pertains equally to the table control, since both systems are substantially the same. To form a basis for numerical control, the independent variable (cutter rotation) is divided into 27 steps. The ordinate erected at each of these stations shows the corresponding position of the tool slide needed to generate the desired cam-gear contour.

Before control data are furnished to the machine, information such as shown in the accompanying table must be computed for any nonlinear gear that is to be produced. The first two columns of this table give the station number and the angular position of the cutter in degrees. The third column of

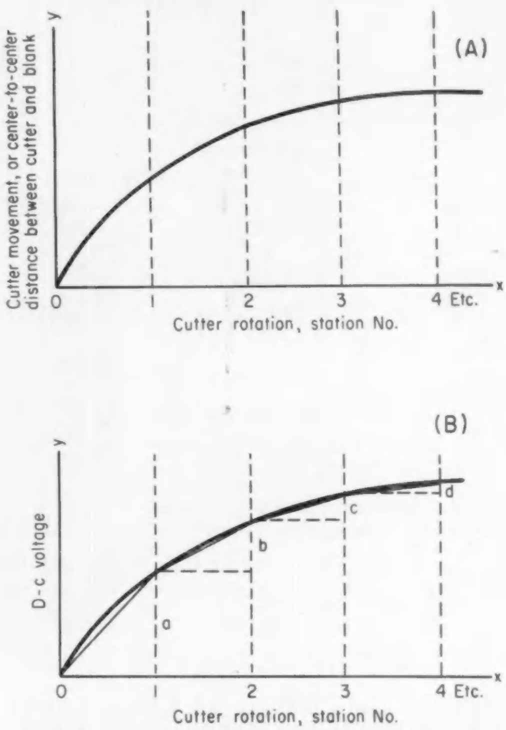


FIG. 5. Nonlinear relationships required for cutter-position control. A—Change in cutter-worktable spacing as a function of cutter rotation. B—Servomotor voltage needed to produce spacing shown in curve A.

TABLE OF INTERPOLATION CONSTANTS

Station	Cutter Rotation, C (deg.)	Table Position, w (rev.)	First Difference, Δ	Second Difference, Δ^2	Third Difference Δ^3
1	−36	0.878181	−0.016983	−0.000441	−0.000057
2	−18	0.861198	−0.017424	−0.000498	−0.000090
3	0	0.845774	−0.017922	−0.000588	−0.000101
4	18	0.825852	−0.018510	−0.000689	−0.000107
5	36	0.807342	−0.019199	−0.000796	−0.000118
—	—	—	—	—	—
—	—	—	—	—	—
26	414	0	−0.064766	+0.001103	+0.000984
27	432	−0.064766	−0.063664	+0.002087	+0.000776

Station	Cutter Rotation C (deg.)	Center-to-Center Distance, D (in.)	First Difference, Δ	Second Difference, Δ^2	Third Difference Δ^3
1	−36	1.955930	−0.040031	−0.003627	+0.000518
2	−18	1.915899	−0.043658	−0.003109	+0.000350
3	0	1.872241	−0.046767	−0.002759	+0.000403
4	18	1.825414	−0.049526	−0.002356	+0.000412
5	36	1.775948	−0.051882	−0.001944	+0.000416
—	—	—	—	—	—
—	—	—	—	—	—
26	414	0.897703	−0.009605	−0.006389	+0.000043
27	432	0.888098	−0.003216	−0.006432	−0.000043

the upper group defines in decimal fractions of a revolution the position that the worktable must assume at each step. The third column of the lower group represents the center-to-center distance in inches between cutter and blank. At present, the tabular values are calculated by hand from formulas describing the desired gear. But with increasing use of the gear shaper, it will become practical to use an automatic computer.

This dimensional information must be translated into dc voltage data for the tool-slide servomotor. How this is done will be explained later; for now assume that the voltage curve depicted in Figure 5B is available. In the actual machine, the voltage information for each cutter station is inscribed on a line of a printed circuit card, which contains as many lines as there are cutter stations. One line is read at each station, where the card is automatically indexed to a new line. Indexing is electrically synchronized with the cutter rotation by three cam-actuated limit switches.

With each reading of a line on the printed-circuit card, an error voltage (a, b, c, etc.) is fed to the potentiometer-servomotor loop for cutter feed. Under the conditions so far assumed, the cutter then moves at some constant speed into or away from the axis of rotation of the gear blank. Because this speed is constant, the sector generated by the cutter will be linear. Or, expressed another way, the center-to-center distance between cutter and work will follow the straight-line paths of the chords depicted in Figure 5B. Since these chords would be reproduced on the surface of the completed cam gear, the simple 27-step input is insufficient to obtain the smooth nonlinear surface contours required. Hence, Norden-Ketay engineers designed a more sophisticated system that can interpolate between the 27 known ordinates and supply a dc control voltage that is a continuous function of the full 360 deg of cutter rotation. The input information is still supplied to the machine in 27 blocks, interpolation between these blocks being accomplished within the machine controls themselves.

Interpolation

The nonlinear functions used in the machine are developed from the Gregory-Newton interpolation formula. Consider the nonlinear curve of Figure 6 for $y=F(u)$, which is typical of the curves describing the relationships between cutter rotation and center-to-center distance as mentioned previously. The equally-spaced values designated as a, a + w, a + 2w, a + 3w, etc., correspond to cutter-station Nos. 1,2,3,4, etc.

The Gregory-Newton theorem states that if the values of y are known for points a, a + w, a + 2w, a + 3w, etc., then all of the values of y between any two adjacent points (between a and a + w for example) can be found by the following formula:

$$y = f(a+kw) = f(a) + x\Delta f(a) + \frac{x(x-1)}{2!}\Delta^2 f(a) + \frac{x(x-1)(x-2)}{3!}\Delta^3 f(a) + \ldots \qquad (1)$$

where
$$\begin{aligned}\Delta f(a) &= f(a+w) - f(a)\\ \Delta^2 f(a) &= f(a+2w) - 2f(a+w) + f(a)\\ \Delta^3 f(a) &= f(a+3w) - 3f(a+2w) + 3f(a+w) - f(a)\end{aligned}$$

The values $\Delta f(a)$, $\Delta^2 f(a)$ and $\Delta^3 f(a)$ are known as the first, second, and third differences of $f(a)$. The symbol x may have any value between 0 and 1 and represents any position between the two adjacent ordinates, Figure 6. In the gear-shaper control, differences higher than the third are neglected. This expedient is practical: the w intervals are sufficiently small so that neglect of the higher-order differences does not introduce appreciable error.

In anticipation of its mechanization, Equation 1 is restated as follows:

$$y = f(a) + x\Delta f(a) + \frac{x(x-1)}{3!}\left[3\Delta^2 f(a) - 2\Delta^3 f(a) + x\Delta^3 f(a)\right]$$
$$= f(a) + x\Delta + \frac{x(x-1)}{3!}\left[3\frac{\Delta^2}{\Delta^3} - 2 + x\right]\Delta^3$$

where the $f(a)$ associated with the various degrees of Δ has been omitted for simplicity. Transposing the third term on the right and adding constant A to both sides:

$$y - \frac{x(x-1)}{3!}\left[3\frac{\Delta^2}{\Delta^3} - 2 + x\right]\Delta^3 + A = f(a) + x\Delta + A \qquad (2)$$

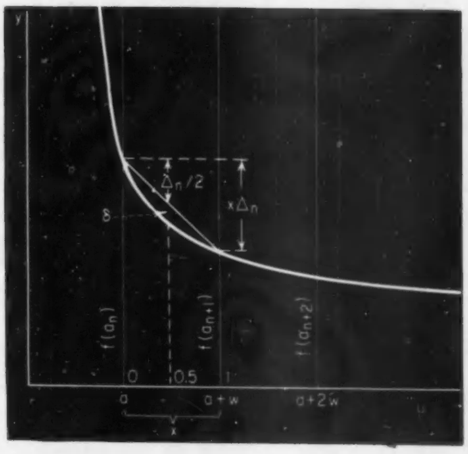
The latter equation defines the magnitude of y for any value x of u between a and a + w. The full range of y values is obtained by varying x from 0 to 1. Now, let $a + nw = a_n$ and the next ordinate $a + (n+1)w = a_{n+1}$. Also, calculate the expressions for $\Delta f(a_n)$, $\Delta^2 f(a_n)$ and $\Delta^3 f(a_n)$. Then a general expression for y can be written for all values of u between a_n and a_{n+1}:

$$y - \frac{x(x-1)}{3!}\left[3\frac{\Delta_n^2}{\Delta_n^3} - 2 + x\right]\Delta^3_n = f(a_n) + x\Delta_n + A \qquad (3)$$

where
$$\begin{aligned}\Delta_n &= \Delta f(a_n)\\ \Delta^2_n &= \Delta^2 f(a_n)\\ \Delta^3_n &= \Delta^3 f(a_n)\\ f(a_n) &= f(a + nw)\end{aligned}$$

Equation 3 contains only two variables, y and x,

FIG. 6. Construction identifies ordinates used in Gregory-Newton interpolation theorem.



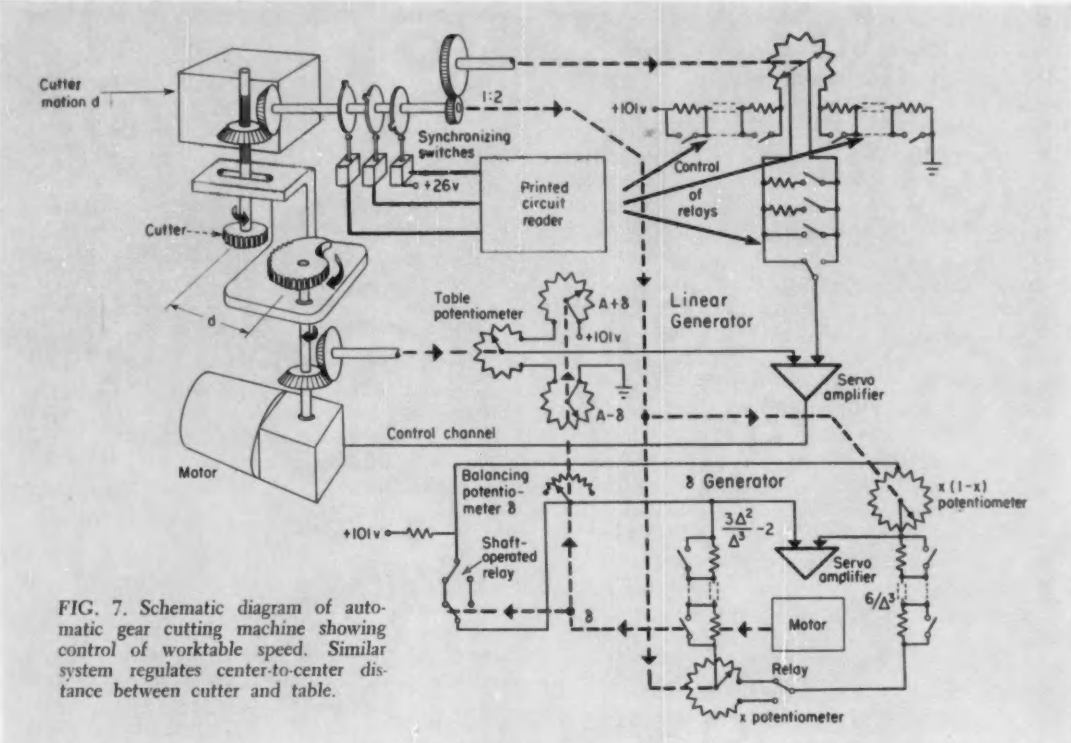


FIG. 7. Schematic diagram of automatic gear cutting machine showing control of worktable speed. Similar system regulates center-to-center distance between cutter and table.

and is the form in which the Gregory-Newton theorem is mechanized within the gear-shaper control system. It might be well to point out here that the equations for a cam gear are fully known by the designers of that gear. Hence, no interpolation is involved if the designers are called up to plot the functions of cutter feed vs. cutter rotation, and table speed vs. cutter rotation. The interpolation concept enters only into the operation of the control system. The purpose of the interpolation is to permit the control system to generate continuous dc voltage signals from a limited number of lines of numerical data. Actually, the gear-shaper control system features computers that convert intermittent numerical data into continuous analog voltages.

Now relate Equation 3 to the physical representation in Figure 6. The smooth curve is the one required. It can be seen by inspection that when $x = 1$ the terms on the right-hand side of Equation 3 define the chord drawn between any two adjacent ordinates. The constant A is an arbitrary constant added to make the computer easier to build. It does not enter into the generation of the function. If these terms only were to be used and x varied in a number of steps between 0 and 1, y would be represented as a series of chords, and this would still not constitute a smooth curve. Hence, a correction is made to convert the series of chords into a satisfactory curve. The magnitude and sign of the correction δ is given by the second term on the left-hand side of Equation 3:

$$\delta = -\frac{x(x-1)}{3!}\left[\frac{3\Delta^2{}_n}{\Delta^3{}_n} - 2 + x\right]\Delta^3{}_n$$

Equation Mechanization

A schematic arrangement of the drive and control for the worktable is depicted in Figure 7. At top left are the three cam-actuated limit switches that synchronize the printed circuit reader with cutter rotation, at top right the potentiometer-relay arrangement (linear generator) by which the right-hand side of Equation 3 is mechanized. These components furnish y in the form of a dc voltage which is a function of the variables and the constant x in this portion of the equation.

The potentiometer is situated in the center of two series strings of resistors. The contacts of an electromagnetic relay are connected across each resistor in each string. By energizing and de-energizing appropriate relays in each string, the potentiometer can be located electrically at any point between 101 volts and ground. Or, the voltage picked off by the brush in the starting position shown can range anywhere from 101 volts to slightly above ground potential.

The resistance value of the two resistor strings represents the ordinate $f(a_n)$. For any given value of $f(a_n)$, an appropriate binary-coded pattern is inscribed on the printed-circuit card. This pattern determines which relays are open and which closed, and hence the voltage at the potentiometer brush.

The potentiometer resistance represents the value of Δ_n and the potentiometer brush represents the variable x. A gear train couples the brush to the cutter drive so that the brush moves through 180 deg for each station of the cutter rotation.

When the cutter reaches station n, the printed-circuit card indexes to line n. Next, the array of relays operates to establish a voltage that is equivalent to $f(a_n)$. As the cutter rotates, it drives the brush so that the voltage equal to $x\ \Delta_n$ is added or subtracted from the $f(a_n)$ voltage. The resultant voltage is amplified and fed to the amplifier of the table drive.

Note that the potentiometer is of the two-brush type. When one brush has zeroed out after 180 deg of movement, the second brush is brought into read position. This occurs just after the printed-circuit card is indexed so that $f(a_{n+1})$ and Δ_{n+1} can be read into the control system.

The relay strings and potentiometers for table rotation are shown in more detail in the schematic wiring diagram, Figure 8. Any even value of resistance from 0 to over 130,000 ohms can be chosen in either string by actuating the proper relays. A single motor-driven potentiometer covering the full range of resistance might have been used in place of the resistor string-potentiometer combination. However, a single potentiometer could not possibly provide this extremely high precision and resolution. Digital information is converted to analog voltages with an accuracy of plus or minus 0.01 percent.

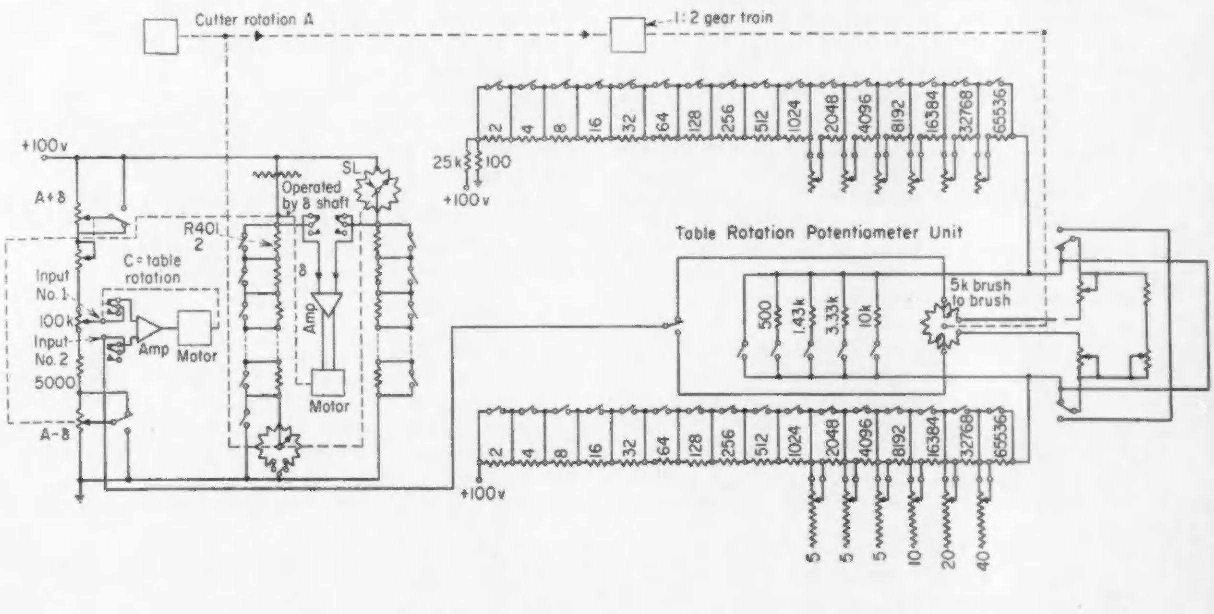
Curvature Correction

Referring again to Figure 7, it is seen that the servo loop for the worktable drive is relatively straightforward. The motor speed is regulated by the output of a servo-amplifier. The error signal on which the amplifier operates consists of the difference between the voltage signal from the linear generator and a feedback voltage. The latter is not, however, simply the output of the table potentiometer, because it remains to apply the correction voltage δ described previously. Hence, the total feedback voltage consists of the output of the table potentiometer as modified by the setting of two servomotor-driven auxiliary potentiometers. The servomotor positions the latter two units to reflect the output of the δ generator.

The δ generator is basically a self-balancing bridge, wherein the balancing pot (representing δ) is the "a" leg. The "b" leg contains the x potentiometer in series with a relay-controlled resistor network, set by printed-circuit card data to represent the quantity $3\Delta^2/\Delta^3 - 2$. The "c" leg is a potentiometer chosen for the variable $x(l-x)$. The quantity $6/\Delta^3$ in the form of a relay-resistor array makes up leg "d". By substituting the aforementioned constants and variables in the fundamental bridge relationship $a = bc/d$, the bridge circuit in Figure 7 will be found to be a mechanized form of Equation 4 for the δ correction.

Here again the relay configuration needed to set up the proper values of $6/\Delta^3$ and $3\Delta^2/\Delta^3 - 2$ for each station of cutter rotation are determined by binary numbers on the printed-circuit card. Brushes of the x and $x(1-x)$ potentiometers are driven from the cutter shaft. When the constants are read into the system at any particular cutter station, the bridge is in balance. However, with continuing cutter rotation, the x and $x(1-x)$ potentiometers upset the balance, feeding a signal to the servo-amplifier con-

FIG. 8. Wiring diagram gives complete array of resistors and potentiometers for generating linear function for table control. Resistances shown are in ohms. Correction generator is at left. Again, similar circuit exists for control of cutter feed.



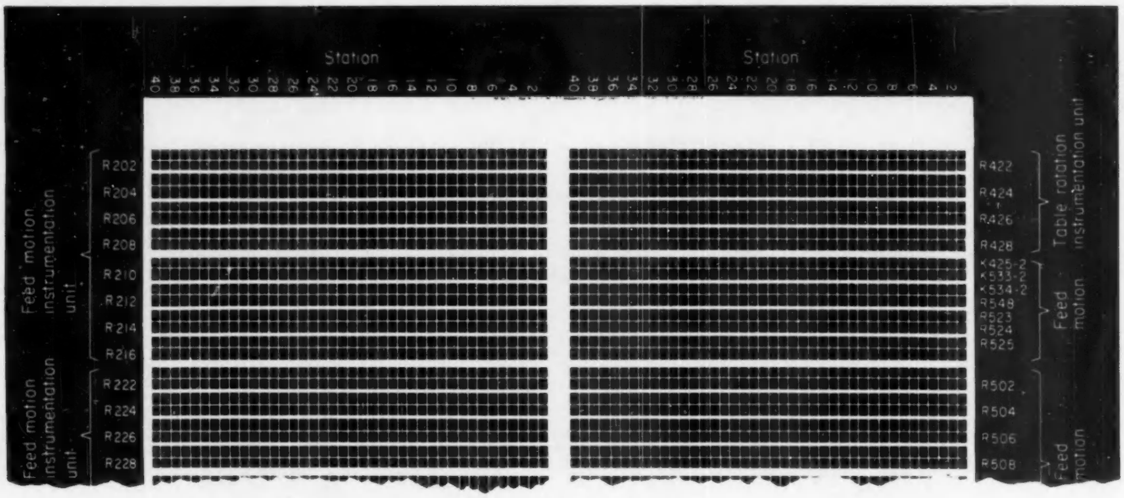


FIG. 9. Portion of chart used in preparing printed-circuit card.

nected across the bridge. The servomotor then drives the potentiometer to attempt to restore balance. Hence, δ continuously reflects changes in the variables x and $x(1-x)$. Simultaneously, the two δ potentiometers in the table feedback circuit are driven to insert the δ correction in the worktable-linear-generator loop.

It has now been shown how the control system computes continuous analog signals from 27 lines of binary data. There are two equivalent control channels in the machine, one for table rotation and one for adjusting center-to-center distance between cutter and blank.

Preparing Output Data

At the present time, the binary notation required for inscription on the printed-circuit card involves a tremendous amount of hand calculations. The mathematical sequence for a given cam gear begins with derivation of the equation for the gear itself. Next, it is necessary to determine the center-to-center-distance vs. cutter rotation and table-position vs. cutter-rotation relationships needed to cut the gear. Once these relationships are available, either in graph or equation form, the dimensional data for the foregoing table can be obtained. Note that the tabulation includes the first, second, and third differences for both worktable-position and center-to-center distance.

A very complex stage in the computations is the conversion of dimensional values into resistance values usable by the machine computer. From such computations comes a chart similar to the dimensional table, but containing resistance values for the first, second, and third differences. The resistance values are entered on the printed-circuit card, Figure 9, in binary form.

The card contains two sections consisting of 40 horizontal data lines. One section pertains to table movement and the other to cutter feed. Although the card has capacity for 40 stations of cutter rotation, only 27 lines are presently employed. The vertical data columns are divided into groups and each group assigned to specific resistor-relay arrangements within the machine computer. A space filled with conductive material indiciates that the corresponding relay is to be energized. The relay for a nonconducting space is deenergized.

So, the preparation of input data is presently tedious. To make way for greater use of the process, a logical step in this development will be the design of a computer or director able to translate gear formulas directly into card data.

Machine Performance

Production runs on the modified gear-shaper testify to the soundness of the design approach and the quality of the control system. Cam gears cut routinely can generate tangent functions accurate to within 1/10 of 1 percent. Backlash is held to a maximum of 0.0005 in. at full-speed production.

The first gears employed in the development of the Mach indicator were cut on a vertical miller and required the services of three men for six weeks. With the computer control system, one man produces the same number of gears in 20 min and with greater accuracy. With the same input card and a special cutter without teeth, the machine can form blanks preparatory to gear shaping.

Norden engineers expect to use these cam gears for substantially reducing weight and complexity of end equipment. They have found that temperature and vibration have little effect on cam-gear function generators, and that their reliability is greater than that of nonlinear potentiometers or other instruments for producing functions. Since cam gears deliver a mechanical output directly from a mechanical input, it is often possible to avoid converting to an electrical analog for function generation.

GETTING MAXIMUM TORQUE out of a two-phase servomotor

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To operate a two-phase servomotor from a single-phase voltage source, the voltage of one of the windings should be shifted 90 deg from the other. This is done by inserting an impedance in series with one of the windings. The magnitude of this impedance can be computed arithmetically[1,2], or by the graphical method presented here, which assures both maximum torque for given operating conditions and a voltage on the reference winding not in excess of its rating.

The motor's power factor and impedance must be known at the operating conditions to use this method. Usually maximum torque is desired under stalled conditions; therefore the examples are worked out for this condition. The method applies to running conditions, too, if the impedance and power factor are known at those conditions. The required data can be obtained from the manufacturer's published information, or from test results.

The graphical construction (refer to Figure 1) is as follows:

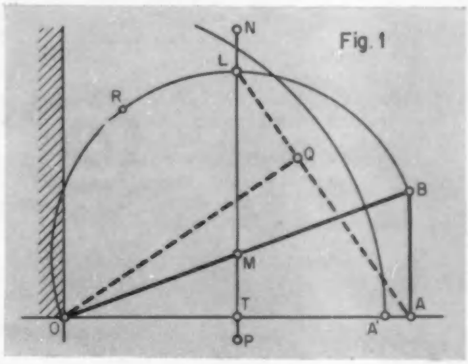
1. Lay off line OA, to a convenient scale, to represent the source voltage.
2. Lay off line OB, at an angle equal to the motor power factor angle, from line OA, and make triangle OAB a right triangle.
3. Construct a semicircle ORB with OB its diameter and M its center.
4. Erect a perpendicular, PN, to OA through point M.
5. Construct part of a circle with center at O such that its radius OA′ represents the voltage rating of the motor's reference winding. (Use same scale as for OA.)
6. This step depends on which of the following conditions is true (see next page):

CASE I—If the intersection of PN and the semicircle ORB lies inside the circle of radius OA′, use this intersection as the locus point L.

CASE II—If the intersection of PN and the semicircle ORB lies outside the circle of radius OA′, use the intersection of the semicircle ORB and the circle of radius OA′ as the locus point L.

CASE III—If the intersection of the semicircle ORB and the circle of radius OA′ lies within the shaded area of Figure 1, use the intersection of the circle of radius OA′ and a line perpendicular to line OA through the point O as the locus point L.

7. Construct a line between L and A.
8. Erect a perpendicular from point O to line LA, and label the point of intersection Q.
9. Let the length of line segment QL represent the known inductive reactance of the motor under the desired operating conditions. The segment QL calibrates an impedance scale in ohms.



10. Then the length of LA, using the scale calibrated in step 9, is equal to the capacitive reactance X_c in ohms required in series with the motor winding and the source. With the source frequency known, the capacitance can be determined from $C = 1/(2\pi f X_c)$. The voltage rating of this capacitor can be determined from the graphical construction, again using the length LA, but now calibrated against the scale specified in step 1.
11. This step applies to CASE III only. Using the scale determined in step 9, lay off from point Q the resistive component of the motor impedance along the line QO. Let this segment be QS. The segment SO, scaled as in step 9, will be the resistance (in ohms) to be placed in series with the capacitor determined in step 10.

The reference winding voltage has been restricted to its rated value for two reasons: first, there will be excessive heating at higher voltages, and second, the flux density in the iron of the motor will be higher with overvoltage and could cause saturation.

For maximum possible torque (ignoring heating and saturation), take as point L the intersection of PN and the semicircle ORB regardless of where it lies with respect to the circle OA′. When a reference winding voltage other than rated is to be used on that winding, use the desired voltage rather than the rated voltage in step 5.

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EXAMPLE I

MOTOR DATA: DIEHL S.S. FPE 25-11 60 cps
At stalled conditions (taken from motor performance data graph supplied by the manufacturer)

$V = 115$ volts; $I = 0.146$ amps

$W = 30.5/2 = 15.25$ watts power per phase

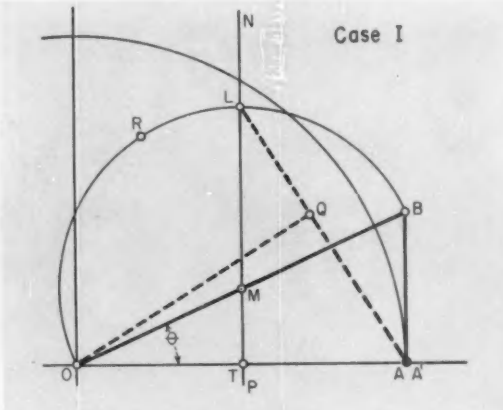
$Z = 115/0.146 = 787$ ohms

$Pf = W/VI = (15.25)/(115)(0.146) = 0.909$

SOURCE VOLTAGE: 115 volts

SOLUTION:

1. Let 2 in. = 115 v; thus 1 in. = 115/2 = 57.5 v. Lay off OA = 2 in. (o.k. for explanation, but use larger scale for actual solutions).
2. Construct OB at an angle of $\theta = \cos^{-1} Pf = \cos^{-1} 0.909 = 24.6$ deg.
3. Construct semicircle ORB.
4. Erect perpendicular PN.
5. Draw circle of radius OA'. Motor voltage = source voltage. Therefore OA = OA'.
6. Since the intersection of PN with the semicircle ORB lies inside of the circle of radius OA', this is CASE I. Therefore L is the intersection of PN and the semicircle ORB.
7. Draw line LA.
8. Erect perpendicular OQ to LA.
9. The reactance of the motor $X = Z \sin \cos^{-1} Pf$
   $X = 787 \sin \cos^{-1} 0.909 = 328$ ohms
   The length of LQ is 0.78 in.; therefore 0.78 in. = 328 ohms; or



1 in. = 328/0.78 = 420 ohms

10. The length of LA is 1.86 in.

X_c = (ohms per inch)(inches) = (420)(1.86) = 780 ohms

$$C = \frac{1}{2\pi f X_c} = \frac{1}{(2\pi)(60)(780)} = 3.40 \times 10^{-6} = 3.4\mu \text{ fds}$$

The voltage rating of this capacitor must be at least

V_c = (volts per inch)(inches) = (57.5)(1.86) = 106.7 v

The phase-splitting impedance will be a capacitor of 3.4 μfds

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EXAMPLE II

MOTOR DATA: GM Size 18 Motor Line 1314 400 cps
At stalled conditions (from manufacturer's data sheet)
Reference phase (per phase)

$V = 115$ v; $I = 0.22$ amps; $W = 16$ watts

$Pf = W/VI = 16/(115)(0.22) = 0.633$

$Z = V/I = 115/0.22 = 522$ ohms

SOURCE VOLTAGE: 110 volts

SOLUTION:

1. Let 2 in. = 110 v or 1 in. = 55 v
   Lay off OA = 2 in.
2. Construct OB at an angle of $\theta = \cos^{-1} Pf = \cos^{-1} 0.633 = 50.7$ deg.
3. Draw semicircle ORB
4. Erect perpendicular PN
5. Draw circle of radius OA'. Motor rating = 115 v; therefore OA' = 15/55 = 2.09 in.
6. Since the intersection of PN and the semicircle ORB lies outside the circle of radius OA' and the intersection of the semicircle ORB, and the circle of radius OA' lies in the shaded portion of Figure 1, choose L to lie on intersection of the circle of radius OA' and the perpendicular to OA through point O. This is clearly CASE III.
7. Construct line LA.
8. Erect perpendicular OQ to LA.
9. Resistance of the motor $R = Z \cos \cos^{-1} Pf$

   $R = Z\ Pf = (522)(0.633) = 331$ ohms

   Reactance of the motor $X = Z \sin \cos^{-1} Pf$

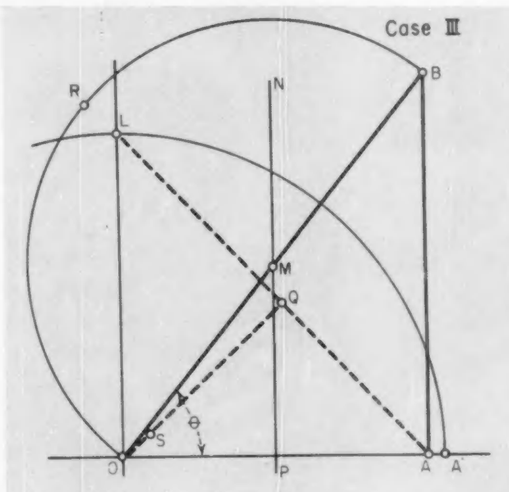
   $X = 522 \sin \cos^{-1} 0.633 = 404$ ohms

   The length of LQ is 1.5 in., so 1.5 in. = 404 ohms, or

   1 in. = 404/1.5 = 270 ohms
10. The length of LA is 2.89 in.

   X_c = (ohms per inch)(inches) = (270)(2.89) = 779 ohms

$$C = \frac{1}{2\pi f X_c} = \frac{1}{(2\pi)(400)(779)} = 5.11\times10^{-7} = 0.511\mu\text{fds}$$



The voltage rating of the capacitor must be at least

V_c = (volts per inch)(inches) = (55)(2.89) = 159 v

11. This is CASE III and the phase-splitting impedance must be a capacitor in series with a resistor. Scaling the resistance to the figure,

   $QS = R = 331/270 = 1.23$ in.

   This results in OS = 0.23 in.; therefore the series resistor is to be

   R_s = (ohms per inch)(inches) = (270)(0.23) = 62 ohms

   The power rating of the resistor must be at least

   $P = I^2R = (0.22)^2(62) = 3$ w

Hence, the phase-splitting impedance is a 62-ohm resistor in series with a capacitor of 0.511 μfds.

Improve Servo Performance with Tachometer Limiting

THE GIST: Tach-stabilized instrument servos, widely used in the control field, pose many problems in increased accuracy requirements for a designer who uses standard techniques. Stringent specifications must often be placed on amplifier gain and gear backlash to obtain the required improved performance. But by adding a simple diode limiter to a servo, the rate response of a tachometer damped system can be greatly improved without modifying any of the existing hardware. Three steps are described for determining the proper limiting value while retaining the original transient response. The resulting overall system is then compared to the system without the limiter.

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The servo designer is frequently confronted with the problem of improving an existing system to meet a desired specification. Though increasing the accuracy and complexity of the individual servo components is a method very often used, there is another way that will sometimes yield the desired performance improvement without further hardware changes. This is to introduce a nonlinear element. Tachometer-damped servos, such as shown in Figure 1, are a good example.

Although tachometer feedback is a very effective stabilizing means, it has this inherent disadvantage: it reduces system gain, thereby increasing servo errors in response to rate inputs. Ordinarily this can be compensated for by increasing amplifier gain, but where high accuracy requirements must be met this may not be practical since the gain might have to be increased to the point where insufficient resolution of the follow-up device or excessive backlash in the gear train results in oscillation.

A better way of effectively increasing system gain is to minimize the tachometer effects when the servo is operating above a specified rate. This is achieved most simply by a diode limiter at the output of the tachometer. The limiter permits a proportional tachometer voltage to be fed back at low servo rates, but clips the tachometer voltage at higher rates, thereby effectively limiting the feedback. The

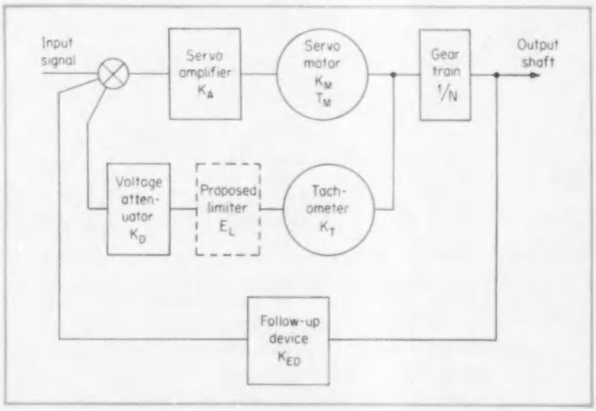

FIG. 1. A typical tachometer-stabilized instrument servo, including proposed limiter.

limiting voltage is selected on the basis of a minimum value that will not appreciably affect the transient response within the linear zone of the system (linear zone being defined as the maximum value of servo error that will not cause the amplifier or motor to saturate). To realize the greatest performance improvement, it is desirable to limit to

as low a value as possible while still maintaining a reasonable transient response.

The following three steps describe a method of selecting the proper limiter and accurately predicting the decrease in servo error.

Step I—Examine the existing system

Four quantities describe the performance of the tachometer-damped servo of Figure 1: velocity error, transient response, static error, and natural frequency. Of these, the main concern is with velocity error and transient response, since static error and natural frequency are unaffected by adding the limiter.

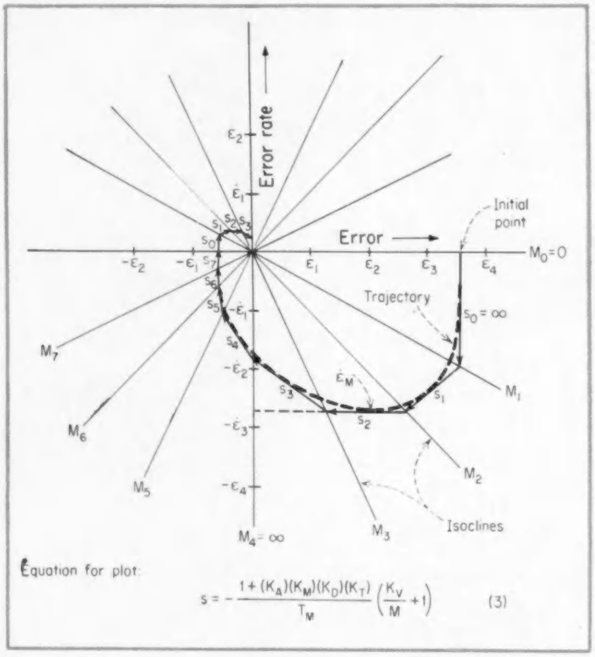

FIG. 2. Phase-plane plot for getting maximum error rate, $\dot{\epsilon}_M$.

The velocity errors are expressed by the velocity constant, K_V, of the system.

$$K_V = \frac{(K_{ED})\,(K_A)\,(K_M)\,(1/N)}{1 + (K_A)\,(K_M)\,(K_D)\,(K_T)} \qquad (1)$$

where the symbols are defined in Figure 1. This value is normally constant, but varies with system rate when the tachometer limiting element is introduced.

The transient response is expressed by the damping ratio, ζ, in the linear zone of the system.

$$\zeta = \frac{1}{2\sqrt{K_V \dfrac{T_M}{1 + (K_A)\,(K_M)\,(K_D)\,(K_T)}}} \qquad (2)$$

where T_M stands for the time constant of the motor.

Equations 1 and 2 should be used to evaluate the existing system without the limiter. Typical damping ratios will fall between 0.5 and 0.6, and velocity constants between 10 and 200 sec^{-1}.

Step II—Plot the transient rates of the servo

To retain the originally designed damping, the limiter must have no effect on tachometer output voltage when the servo is responding to transients in the linear zone of operation. To make sure of this, determine the maximum rate that the servo attains during transients and adjust the limiting accordingly.

A phase-plane plot of error versus error rate will yield the necessary information. This plot is most easily constructed graphically by plotting a series of isoclines having an arbitrary slope M and passing through the origin as shown in Figure 2. An isocline is a straight line of slope M that connects all points where the phase-plane trajectory has the same slope s in accordance with the following equation:

$$s = \frac{1 + (K_A)\,(K_M)\,(K_D)\,(K_T)}{-\,T_M}\left(\frac{K_V}{M} + 1\right) \qquad (3)$$

The phase-plane diagram can be made as accurate as desired by drawing a large number of isoclines. The initial point, ϵ, of the trajectory has an amplitude equal to the size of the step applied to the servo. The path is extended from this point by constructing a series of straight-line segments, each segment beginning at an isocline and continuing until it intersects the next isocline. The segment may have a slope, s, corresponding to that determined from Equation 3 for either isocline, or, as a better approximation, corresponding to the mean of the slopes determined for the two isoclines. The segments of slope s are continued from one isocline to the next until the path is completed.

The magnitude of the step ϵ can be determined from the linear zone of the system. Assuming that the servo amplifier will saturate before the motor, the maximum value that ϵ may have is given by

$$\epsilon = \frac{E_{OM}}{(K_A)\,(K_{ED})} \qquad (4)$$

where E_{OM} is the maximum amplifier output voltage.

The maximum error rate and thus the maximum servo rate appears at point $\dot{\epsilon}_M$ on Figure 2. This rate is used in determining the proper limiting voltage of the tachometer.

Step III—Determine tachometer limiting voltage

After establishing the maximum servo rate for a specified step input, the resulting tachometer voltage can be determined and the system arranged to limit to this voltage value.

The limiting voltage is given by

$$E_L = (\dot{\epsilon}_M)\,(N)\,(K_T) \qquad (5)$$

This represents the minimum limiting value that can be used without affecting the transient response of the servo.

Since the tachometer constant, K_T, is always

$$K_T = \frac{\text{tachometer output voltage}}{\text{tachometer speed}}$$

the effective value of the constant K_T at speeds above the point where clipping takes place is

$$K_T = \frac{E_L}{\text{tachometer speed}} \tag{6}$$

Thus the effective K_T decreases with servo rates above a certain critical value. The effect of this on the various servo parameters is shown in Figure 3.

Substituting Equation 6 in Equation 1, the maximum velocity constant that can be achieved is

$$K_{VM} = \frac{(K_{ED})\,(K_A)\,(K_M)\,(1/N)}{1 + (K_A)\,(K_M)\,(K_D)\,\dfrac{E_L}{R_M N}} \tag{7}$$

where R_M is the maximum commanded rate of the servo. The maximum value of the velocity-lag error is therefore:

$$\epsilon_{VM} = \frac{R_M}{K_{VM}} \tag{8}$$

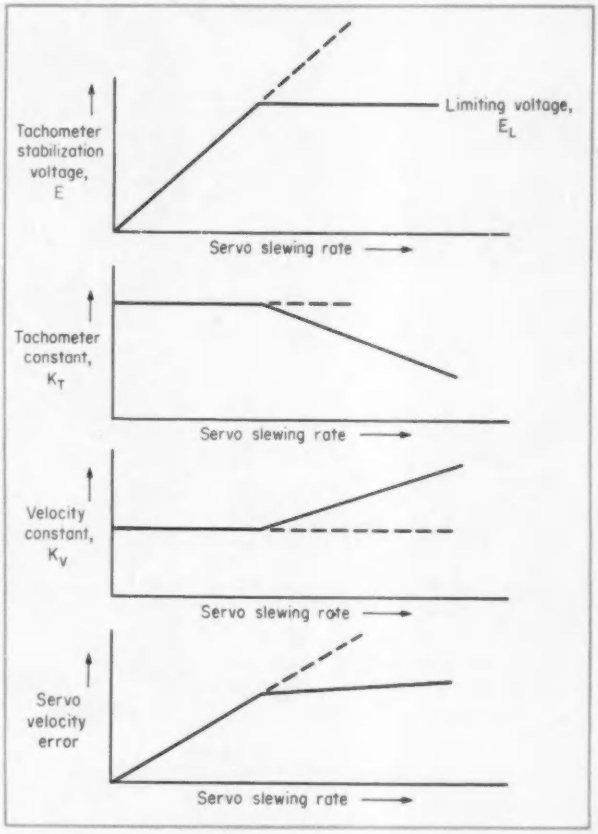

FIG. 3. The effect of limiting on various servo parameters. Dashed lines show operation without limiter.

SOLVING A TYPICAL PROBLEM

THE PROBLEM—An instrument servo has been designed to follow the roll angle of an aircraft. The output shaft of the servo is used to position resolvers that provide trigonometric functions of the roll angle to various portions of a computer. The maximum tolerable velocity error between the aircraft and the shaft is 1.5 deg. The maximum roll rate is 100 deg/sec. Therefore, the required velocity constant is

$$K_V = \frac{100 \text{ deg/sec}}{1.5 \text{ deg}} = 66.7 \text{ sec}^{-1}$$

The required damping ratio is 0.6. The system shown in Figure 4 meets these requirements.

Further restrictions later placed on the servo required that the velocity error not exceed 1 deg. This means the velocity constant must be increased to 100 sec^{-1}. A standard linear servo analysis showed that the amplifier gain, K_A, must be increased from 500 to 1,100 volts/volt, with a subsequent change of K_D from 0.118 to 0.097 volts/volt to maintain proper damping. The increased amplifier gain proved to be intolerable because of instability resulting from gear train backlash.

AND THE SOLUTION—Using the three steps outlined, tachometer limiting was added with K_A maintained at 500 volts/volt, K_D at 0.118 volts/volt.

Step I—From Equation 1, the velocity constant of the original servo is

$$K_V = \frac{(0.2 \text{ v/deg})\,(500 \text{ v/v})\,(400 \text{ deg/sec/v})\,(1/200)}{1 + (500 \text{ v/v})\,(400 \text{ deg/sec/v})(0.08\text{x}10^{-3} \text{v/deg/sec})(0.118\text{v/v})}$$

$$K_V = 69.2 \text{ sec}^{-1}$$

and from Equation 2 the damping ratio is

$$\zeta = 0.59$$

Step II—Choose the scales for drawing the phase-plane plot. The extreme of the error rate scale, $\dot{\epsilon}$, is determined by the maximum servo rate, in this case 100 deg/sec. The extreme of the error scale, ϵ, is the maximum input step as determined from Equation 4. Since maximum amplifier output voltage is 100 volts, the initial point is:

$$\epsilon = \frac{100 \text{ volts}}{(0.2 \text{ volts/deg})\,(500 \text{ volts/volt})} = 1 \text{ deg}$$

The series of isoclines having various slopes M are plotted in Figure 5. Using Equation 3, values of slope s are calculated for the various slopes M. From the trajectory, the value of $\dot{\epsilon}_M$ is 52 deg/sec.

Step III—Determine the limiting voltage E_L from Equation 5.

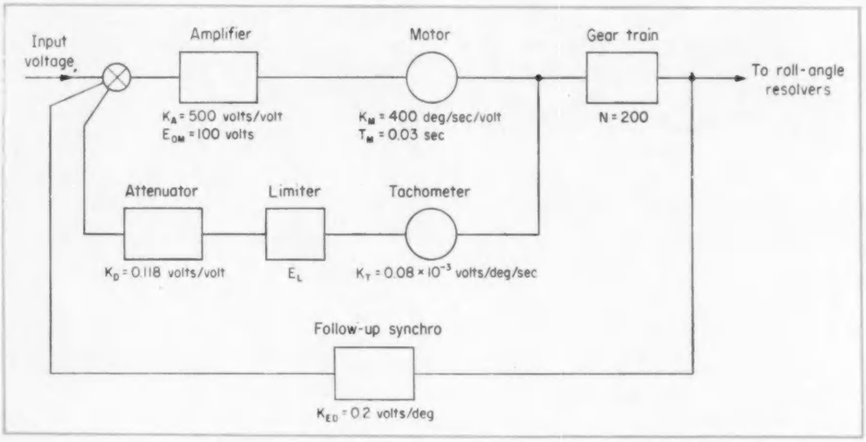

FIG. 4. Servo configuration and constants for typical problem.

$E_L = (52 \text{ deg/sec})\,(200)\,(0.08\text{x}10^{-3}\text{ v/deg/sec}) = 0.831\text{ v}$

Add a limiter to the system that will clip the tachometer output voltage above 0.83 volts.

The resulting velocity constant can now be determined from Equation 7.

$$K_{VM} = \frac{(0.2)(500)(400)(1/200)}{1+(500)(400)(0.118)[0.83/(100)(200)]}$$

$$K_{VM} = 101 \text{ sec}^{-1}$$

Then determine the maximum servo following error from Equation 8.

$$\epsilon_{VM} = \frac{100 \text{ deg/sec}}{101 \text{ sec}^{-1}} \cong 1 \text{ deg}$$

Adding the limiter improved servo performance by decreasing velocity errors by 44 percent. This was done without detracting from other performance characteristics.

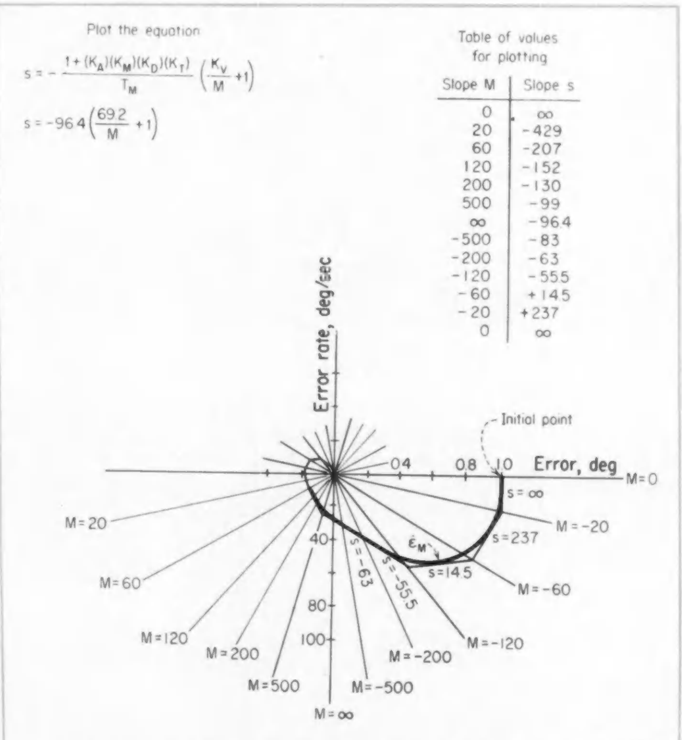

FIG. 5. Plotting the phase-plane trajectory for the typical problem.

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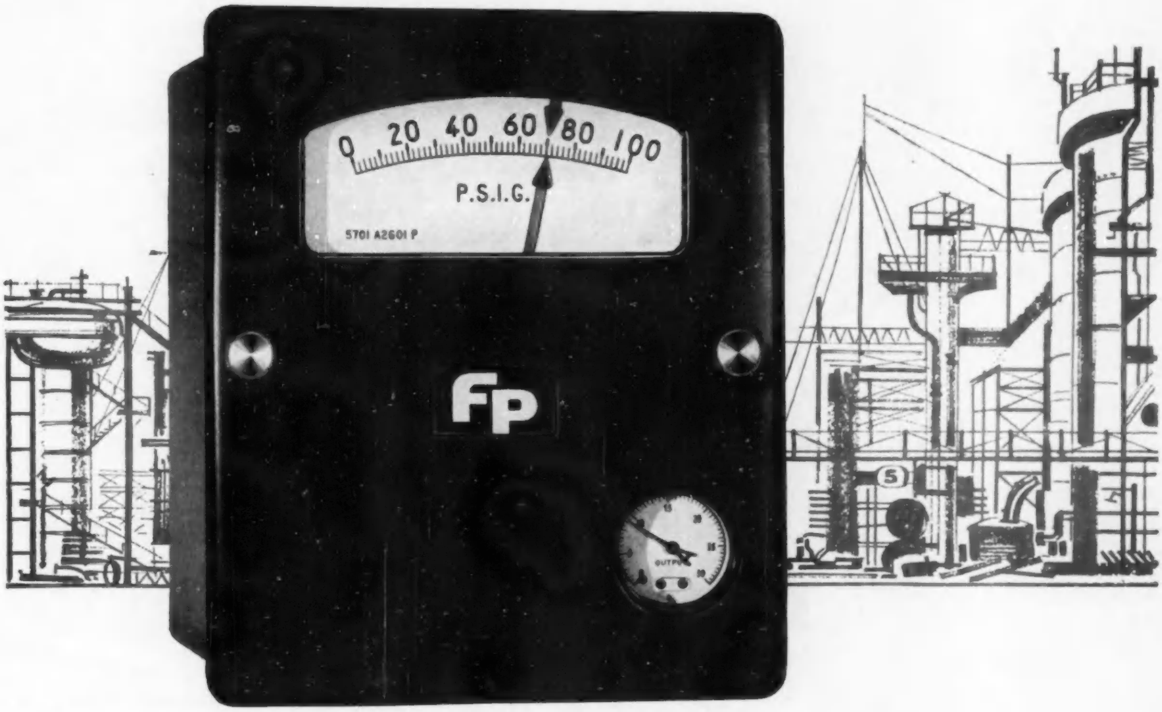

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Complete Process Instrumentation

Fitting the Digital Computer Into Process Control

Applying digital control to a process involves much more than simply connecting a computer into the system. Prerequisites to integrated design are familiarity with digital techniques and lots more knowledge about the process itself than was needed before. The resulting complexity of the design efforts may bar wider computer usage unless orderly approaches to system analysis and synthesis are mastered. Here, a systematic approach is described and illustrated by a case in point.

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The Ramo-Wooldridge Corp.

The move to the revolutionary "computer-type" control has been slow in the process industries, despite the fact that the groundwork for such control is already well established. As a result of pioneering work done in other fields, the hardware and the design techniques for digital controls are already available. Most people in the process areas are already alert to the many advantages promised by the new systems: advantages such as improved product quality, increased yield, and reduced operating costs. But, certain obstacles are holding up more widespread application.

One major problem stems from the fact that before digital controls can be applied to a given process, formulas must be developed relating operating variables to the measured variables and to the desired product characteristics. However, at the present time very few processes are so completely understood that all variables can be related on a theoretical basis.

Another impediment is the lack of instrumentation for measuring some process variables. The fast-moving instrument industry, however, is making rapid progress in easing this restriction. There are variables that cannot be measured directly, of course, but even this obstacle may yield to some indirect method of measurement.

Reliability is an important factor in digital control systems and must be considered as a system parameter. Techniques for reliability are manifold, but are not included within the scope of this article.

These problems, and others that arise in the course of applying digital control systems to new processes, can best be solved by a careful analysis of the process and of the possible control systems that may be employed. A systematic approach to analysis and synthesis will now be described. This will be followed by a case-history study of a typical design project. A typical "control engineering team" for system design must have experience and know-how in process engineering, instruments, computers, servo theory, etc.

SYSTEM ANALYSIS

The first step in designing a digital control system is to analyze the process to be controlled. A thorough appraisal is assured if the following organized approach is taken.

1. Decide upon limits or boundaries of the process. In many situations the limits will be obvious. A plant may make only one product, and the designer's problem may be to control the entire plant. On the other hand, the process to be controlled may be only one of a large number in the plant, all of which interact. Setting a boundary to the process to be controlled is then a very delicate matter, for a solution that might optimize it might at the same time affect other processes in an adverse way.

2. Define process objectives. Process objectives must be expressed initially in economic terms. One usual objective is to produce the maximum amount of a product having specified characteristics from certain raw materials at the minimum processing cost. It is necessary, therefore, to examine and place values on all of the materials and energies that enter and leave the previously established process boundaries, and to determine other operating costs (e.g., maintenance costs) that cannot be expressed in terms of inputs.

The process economics are not always easily evaluated. For example, it may be very difficult to assign a value to improved product quality. It may be necessary in one instance to improve quality in order to meet the quality characteristics of a competitive product, or in another instance, to use it in advertising as a means of increasing sales. In either case, the designer will have to place some arbitrary value upon improved quality.

The process objectives in the control-system design should be expressed explicitly so that control actions taken by the digital control system can be based continuously on their calculated effects on process economics. On the other hand, it may be that process economics are so straightforward that certain simplifications can be made and subsidiary operating objectives

may be set up, such as maximizing process throughput or minimizing raw material costs. Further, a quick appraisal of the economics may disclose that the potential payoff for improved control of a given process is so small that there is no point in proceeding further with digital-system design.

3. Study process variables. These variables may be divided into three groups: (1) the independent variables, such as the raw material chemical properties and amounts available; (2) the operating and intermediate variables that serve to measure and control the state of the process or operation: temperatures, pressures, liquid levels, flow rates, chemical compositions, etc., at points in the process between the raw material and the end product; (3) the product variables, which determine the character of the end-product and must be controlled: octane number, density, viscosity, chemical composition, etc.

The general problem is to manipulate the intermediate variables so as to compensate for variations in the independent variables and still produce a product whose characteristics lie in a certain range as measured by the product variables. It is therefore very important to gather all available data on each of the process variables. Some of these data will be in the form of specifications, but most will be in the form of historical records showing past variability in operation of the process under study. It is also important to find out which process variables may be controlled directly by existing equipment or by the installation of new equipment, and to determine the range over which control may be exercised. If it develops that some critical control variable has a range too limited for optimum control, it may be necessary to explore the cost of increasing the control range.

4. Analyze equipment and operating procedures. The layout of the plant, maximum allowable temperatures and pressures, capacities of conveyor belts and pipes, nominal ratings of compressors, generators, etc., are all important. Their description serves, among other things, to delineate the process bottlenecks, and to indicate where excess capacity is available. Furthermore, a study of the existing control system will disclose what correlations between the intermediate and the product variables are presently employed to meet product and process specifications in the face of variations in the independent variables. A complete analysis will also reveal what actions should be taken under emergency conditions.

5. Determine process dynamics. The speed with which the process responds to changes in the independent and the intermediate variables subject to direct control is a very important aspect of any control-system analysis. Knowing this speed, it is possible to predict how the system will react to process changes. Data on system dynamics may be gathered from theoretical studies, from manufacturers' data, from analysis of operating records, and from plant experiments. The interaction between computer speed and process dynamics will be less severe if the computer output adjusts the set-point of a conventional controller rather than controlling a process variable directly.

6. Analyze plant instrumentation. Finally, the system designer must collect information on measurements and measuring equipment. He should determine, if possible, the accuracy of the equipment that supplied him with the operating records so that he can judge whether a variability in a parameter recorded on a certain day, for example, is a significant variation or one which may be ascribed to an error in the measurement. An investigation must also be made of the accuracy and dynamic characteristics of whatever new instruments may be employed in a new control system. In the beginning, it is of course not apparent which of the many process variables should be measured, and therefore what new instruments will be necessary and should be investigated. This part of the investigation will be guided as time goes on partly by the parameters that appear to be important, and partly by the ease or difficulty with which various parameters can be measured.

System design

When the system analysis is complete, the designer should have in mind a complete picture of the economics, physical and chemical characteristics, and existing control of the process. He must now organize and analyze his data, and synthesize or invent a control system. Some of the steps in organizing and analyzing data will now be described.

1. *THEORETICAL ANALYSIS OF PROCESS.* A theoretical and fundamental approach to the process under study often makes it possible for the designer to derive approximate relationships among some of the important variables. Such a derivation may necessarily be based on a very much simplified model of the process, in which the effects of many variables are completely ignored.

2. *CORRELATION OF VARIABLES.* Unfortunately, most processes are so complex as to defy complete theoretical analysis. Therefore, when analysis and approximation have yielded as much information as possible, it is necessary to return to the operating data and records that have been collected and to try to derive from these data relationships between the independent and intermediate variables and the product variables. The methods and procedures of mathematical statistics must be brought to bear upon the data, and some correlations between various operating variables must be established. Often, because of the errors in measuring devices, the large number of variables that actually affect the process, and the incompleteness of process data available, it is not possible to obtain a very good fit between the data and an analytic curve. Nevertheless, any correlation at all will serve as a basis for control, and will in general provide a better basis than the rules of thumb employed by human operators. Furthermore, after the digital-control system is installed, it may be used to gather more accurate and more detailed data that may serve as a basis for improved correlations.

3. *INVENTION.* At some point along the way, when the process is fairly well understood and the importance of the various process variables has been established, the designer must invent a control system. This consists of choosing an appropriate set of variables to be measured and controlled, and determining the relationships and rules connecting these variables, provided that:

a. Process objectives are met.
b. The chosen variables can be measured and controlled with existing equipment.
c. The operation of the control system and the process results in a total system that is dynamically stable.
d. None of the limitations on equipment capacity is exceeded.

The designer will often be able to suggest several ways (conventional, digital, or both) of improving control over the process, all varying in degree of complexity and expense. It will be necessary to evaluate the costs and payoffs for each of these prospective solutions to the control problem.

4. *SPECIFICATION OF SYSTEM COMPONENTS.* When the general plan for the control system has been laid out, the designer is in a position to fill in details and to examine, evaluate, and overcome the obstacles that stand between his initial idea and the completed system.

Assuming that a digital control sys-

tem is found to be the most economical solution to the control problem, the designer must specify computer speed, accuracy, number and kind of input and output channels, and the functions that the computer must perform. If the computer is to be connected directly to input analog-to-digital transducers, the transducers and analog-to-digital converters must be specified and the details of their connection to the computer worked out. If the computer is to control the set-point of a conventional pneumatic controller, the necessary components must be described. If it is to read numerical data entered by an operator, and print out data for monitoring by supervisor, the type and operating speed of input and output devices must be shown.

5. SYSTEM OPERATION. The system synthesis is complete only when the designer has described in detail exactly how the various system components operate together, and what procedures (if any) the human operator must follow. For a digital-control system, the designer must specify both the computer program and the operator functions for four different modes of operation: start-up, shutdown, normal operating conditions, and emergency operating conditions. The computer program determines the sequence in which input data are read; the methods used to interpret input data; the calculations employed to relate input and controlled variables; the sequence of adjustments made in controlled variables; the kind and amount of information printed out; the methods and procedures employed by the computer to check the calibration of an output device; and the methods used by the computer to check its own operations.

For the operator, the designer must specify a reaction for each anticipated computer output. Ordinarily, the operator may do nothing more than survey process operation by keeping an eye on instruments and computer output. Under certain conditions, the computer will print out data which require special action to be taken by the operator. Under other circumstances, the computer may detect an error in itself or in some instrument associated with it and may print out an alarm to the operator together with some indication of what has gone wrong. Depending on what the trouble is, the operator may then override computer operation and take charge of the process himself, or request maintenance for instrument or computer, or both. In addition to preparing for these anticipated difficulties and situations, the designer must state some general rules indicating under what conditions the operator should override the computer control on his own initiative.

DESIGN CASE HISTORY

A simplified and idealized application will illustrate some of the problems that arise in system analysis and design and will show the results that digital control can provide. A chemical process, Figure 1, consists of a reactor, a heat exchanger, a catalyst-separating system, and a fractionating tower. The raw material enters at point 1 with flow rate f_1 and proceeds through a heat exchanger which increases its temperature. The material at point 1 contains x_1 percent of the primary reactant, and $(1 - x_1)$ percent of an inert material that does not enter into the reaction. After the heat exchanger, the mixture enters the reactor where a catalyst is added at flow rate f_2. The reaction is exothermic.

The hot product leaves the reactor, passes through a heat exchanger where it is cooled and the reactor feed is heated, and enters the catalyst separator. After removal of the catalyst, the remaining material, consisting of inert substance, the product, and that part of the reactant not converted to product, passes point 2 and enters a fractionating tower. Here the product is separated from the other components. The product leaves the process at rate f_3.

The graphs of Figure 2 indicate the relative amounts of the various components at the two process points. The process boundaries will be taken to be those indicated in Figure 1. A study of the relationship between this process and the rest of the operation of the plant discloses the following boundary conditions for the study: (1) Incoming material is available at instantaneous flow rate f_o, and contains x_1 percent of reactant. Both of these quantities are independent variables that may vary over wide ranges. Often there is more of this incoming material than the reactor can use, and whatever is not used will be employed elsewhere in the plant. (2) Product-flow rate f_3 can vary over a wide range without effect on the rest of the plant.

The objective is to obtain maximum operating profit from the operation of the unit. It will be assumed that maintenance costs are constant, unaffected by operation of the process. For this reason and because in general

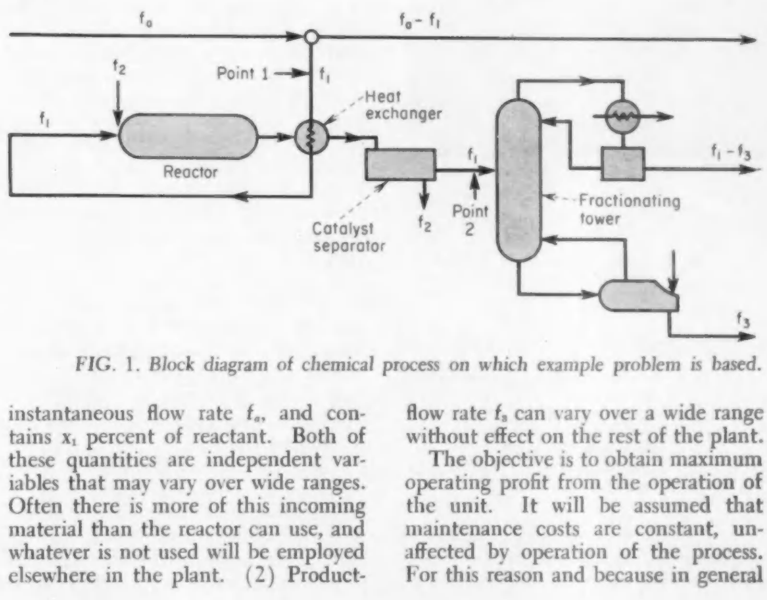
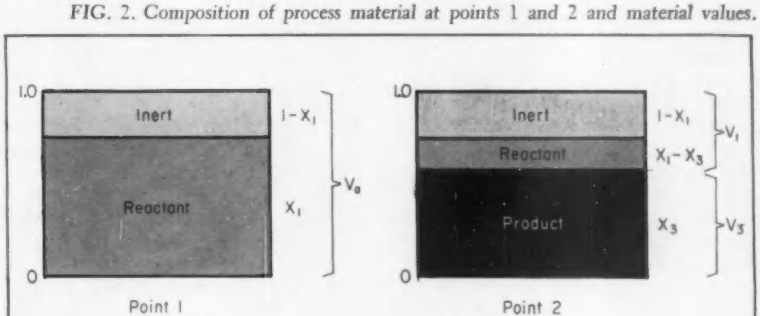


FIG. 1. Block diagram of chemical process on which example problem is based.

FIG. 2. Composition of process material at points 1 and 2 and material values.



the operation of the unit from one minute to the next does not affect its operation in the future, the act of maximizing total operating profit is equivalent to maximizing the instantaneous profit derived from the unit. An expression for the profit follows:

$$P = f_1 x_3 v_3 + f_1(1-x_3)\, v_1 + (f_a - f_1)\, v_a - f_a v_a - f_2 v_2 - b$$
$$= f_1 x_3(v_3 - v_1) - f_1(v_a - v_1) - f_2 v_2 - b \quad (1)$$

where x_3 = weight percentage of desired product at point 2
f_a = flow rate of incoming material
f_1 = flow rate of material at points 1 and 2
$f_1 x_3$ = flow rate of product at point 1

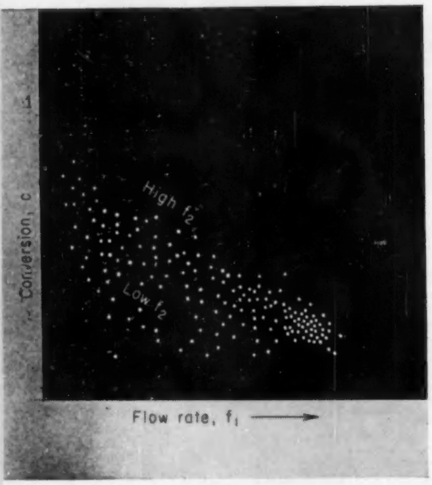


FIG. 3. Conversion as a function of flow rate f_1, shows effects of catalyst flow rate f_2.

v_3 = value of desired product at point 2
v_1 = value of that material at point 2 which is not product
v_a = value of raw material, if not processed in this unit
f_2 = flow rate of catalyst
v_2 = loss in value of catalyst in process
b = constant operating costs

The effect of heat losses on cost is negligible. The catalyst, on the other hand, is very expensive and is one of the major costs of operation.

The independent variables are the incoming flow rate f_a and x_1, not susceptible to control. The only product variable is x_3, the concentration of the desirable product in the output of the catalyst separator. The intermediate variables are f_1 and f_2, the flow rates of raw material and catalyst into the reactor, respectively. Other important intermediate variables are reactor temperature and pressure, catalyst-separator level, and fractionating-tower operating conditions. In the existing installation, the catalyst separator provides the bottleneck on unit capacity and determines the upper limits on the intermediate variables f_1 and f_2. The total flow into the separator may not exceed f_{max}, and the catalyst flow rate may not exceed f_{2max}. Or,

$$f_1 + f_2 \leqq f_{max}$$
$$f_2 \leqq f_{2max} \quad (2)$$

The operation of the reactor is generally specified by quoting a "conversion" for the reactor, defined as the ratio of the amount of desired product at point 2 to the amount of that raw material at point 1 which theoretically could have been converted entirely to desired product. If this is expressed as $c = x_3/x_1$, x_3 can be replaced in Equation 1 by cx_1, obtaining

$$P = f_1 c x_1(v_3 - v_1) - f_1(v_a - v_1) - f_2 v_2 - k \quad (3)$$

In Figure 3, conversion c is plotted as a function of f_1 from data collected in past operating experience with this unit. Each point represents a daily average of conversion and input flow, which may fluctuate widely over the period of a day.

Conversion is known to be a function of reactor temperature and pressure, catalyst flow, and feed flow. The temperature and pressure variations are such that ideal operation is clearly at the maximum safe temperature and pressure ratings of the process equipment. Conversion is also known to increase with catalyst-flow rate, as indicated in Figure 3.

In the existing system, reactor temperature and pressure are controlled at their desired maximums by conventional recorders and controllers. The separation of feedstock flow into reactor feed and by-pass feed, and the ratio of catalyst-feed rate to reactor-feed rate is controlled by an operator, who adjusts the two flow rates compatible with process limitations and with the established boundary conditions.

The dynamics of the process (the variation in output parameters as a function of time with variations on the independent and operating variables) are largely unknown. Experience indicates that a change in flow at the input to the reactor reaches its final value at the fractionating-tower feed about 15 min later, and at the fractionating-tower output about 45 min later.

The data collected and plotted in Figure 3 are based on a laboratory analysis of samples collected three times a day at the process. The flow f_1 in Figure 3 is an average value of flow over the same time interval for which the average conversion was calculated. To each point in Figure 3 there is also assigned a value of catalyst flow rate f_2 and this is also obtained by averaging that flow over the entire day. An investigation of available equipment for analyzing continuously the streams at points 1 and 2 indicates that an instrument can be found to measure x_1 at point 1. However, no instrument is available to continuously and accurately measure product percentage x_3 at point 2, and the presence of the product makes it impossible to measure the reactant percentage at point 2.

System synthesis

A theoretical analysis of the kinetics of the reaction and of the relationship between all process variables proves impossible. However, a careful study of the available operating data on conversion and on the relationship between feed-flow rate, catalyst-flow rate, and conversion makes it possible to establish certain correlations between these variables and to write a mathematical expression relating them that provides the best possible fit to available operating data. In the equation below expressing this mathematical relationship, constants k_1, k_2, and k_3 are chosen to make this curve best fit the data of Figure 3:

$$c = \frac{k_2 f_2}{1 + k_3 f_2}\, e^{-k_1 f_1} \quad (4)$$

This equation for c is plotted in Figure 4, wherein the maximum values for catalyst-flow rate and for combined catalyst- and feed-flow rates are also indicated.

Unfortunately, Equation 4 does not exactly describe the effect of all variables on conversion. In particular, there is reason to believe that unpredictable and unidentifiable factors tend to shift the conversion curves from one day to another and even from one eight-hour period to another. A typical set of operating points taken on two different days is shown in Figure 5, and the curve of Equation 4 is fitted to each set of points by suitably choosing parameters k_1, k_2, and k_3.

Reviewing his collection of data at this point, the system designer can make the following statements: the objective of any control system is to maximize the operating profit function P of Equation 3; in Equation 3 the initial percentage of reactant in the feed (x_1) is an independent variable beyond control; the conversion c is a function of f_1 and f_2 whose general form is indicated by Equation 4; the two flow rates f_1 and f_2 are the intermediate variables subject to control; the physical characteristics of the process equipment set upper limits on these flow rates, Equation 2.

The control problem is now specified in enough detail so that the designer can see how it might operate. The data of Figure 3 must be used

Compare these three values of
P. The process-flow rates should

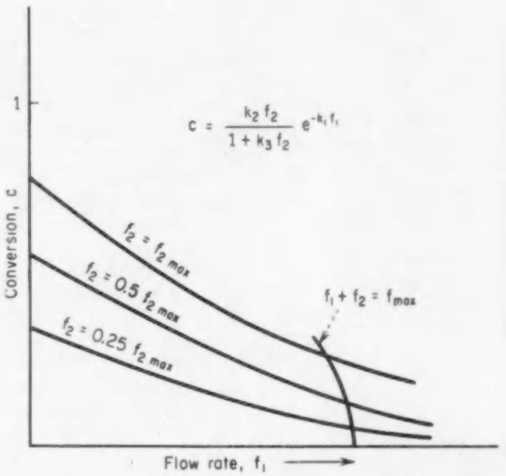


FIG. 4. Curves of conversion vs. flow rate f_1 for three specific catalyst flow rates f_2.

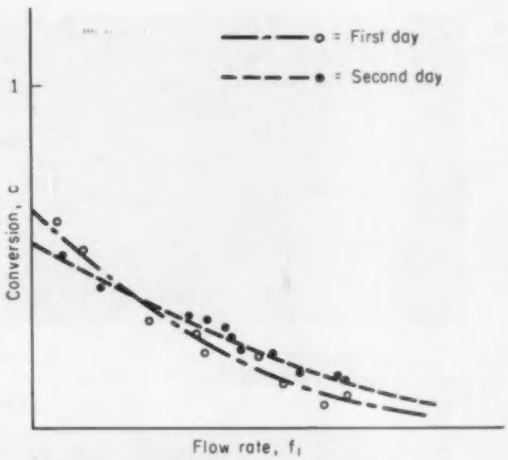


FIG. 5. Relationship of conversion and flow rate on two different days for constant f_2.

to evaluate constants k_1, k_2, and k_3 of Equation 4 and provide a good fit of the curves to that data. With these constants determined, there are particular values of f_1 and f_2 which maximize the profit of Equation 3 for every value of reactant concentration x_1 (see Equations 5 and 6 below). In its simplest form, the control system must therefore measure x_1; must calculate the appropriate values of f_1 and f_2; and must adjust the corresponding flow-control valves in the process.

The control system will, however, be complicated by several other factors. First, it may be that there is not enough feed available to obtain maximum theoretical profit from the operation. Second, the optimum values of f_1 and f_2 may be such that the capacity of process equipment is exceeded. Finally, the control system must continually make sure that the functional relationship it uses to relate conversion with catalyst and feed flow rates, Equation 4, accurately represents plant conditions at the time.

Computer control. To control the process, a computer must first find the maximum value for P of Equation 3, subject to the restriction that conversion c is a function of f_1 and f_2 as shown in Equation 4. Substituting Equation 4 in Equation 3, then taking the partial derivative of P with respect to f_1, and setting it equal to zero,

$$c\,(1 - k_1 f_1) = \frac{v_s - v_1}{x_1\,(v_2 - v_1)} \qquad (5)$$

Similarly, setting the partial derivative of P with respect to f_2 equal to zero,

$$\frac{f_1 c}{f_2(1 + k_3 f_2)} = \frac{v_2}{x_1(v_2 - v_1)} \qquad (6)$$

The reactant feed concentration x_1 of Equations 5 and 6 is measured every time new values for f_1 and f_2 are to be determined. All of the other constants in Equations 5 and 6, and Equation 4 (which relates conversion to the unknown quantities) are known. Therefore, the computer must solve Equations 5 and 6 simultaneously for the flow rates f_1 and f_2, after substituting c from Equation 4. The result will be the optimal values for flow, which will be called f_{10} and f_{20}.

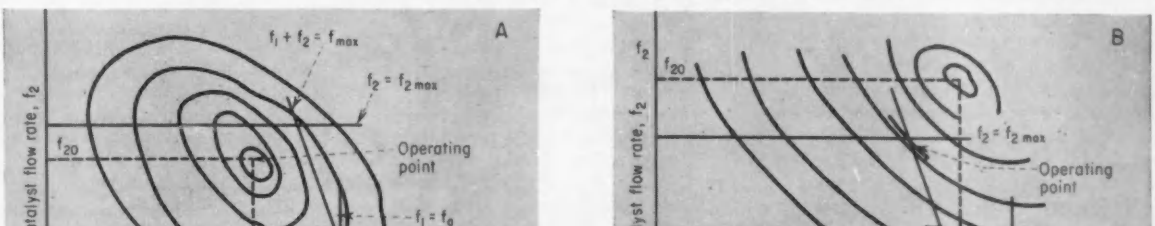
The computer must now determine whether the optimal flow rates are obtainable in practice, and must determine what flow rates should actually be used if they are not. The effect of process limitations is most easily understood with reference to Figure 6, wherein contours representing equal values of P in the f_1 f_2 plane are plotted. Because of the nature of Equations 3 and 4, there is only one point of maximum profit, represented by the coordinates (f_{10}, f_{20}). Equipment limitations are represented by the straight lines,

$$f_2 = f_{2max} \qquad (7)$$

$$f_1 + f_2 = f_{max} \qquad (8)$$

and the feed-availability limitation is

FIG. 6. Plots of constant profit in the f_1 f_2 plane. A — Maximum operating profit realizable at (f_{10}, f_{20}); B — Maximum operating profit not realizable at (f_{10}, f_{20}).



Equation 4 to a set of 20 points all clustered together in a small area of

where f_s = flow rate of product from fractionating system, and

trol system. However, the feedback is smoothed and delayed to such an

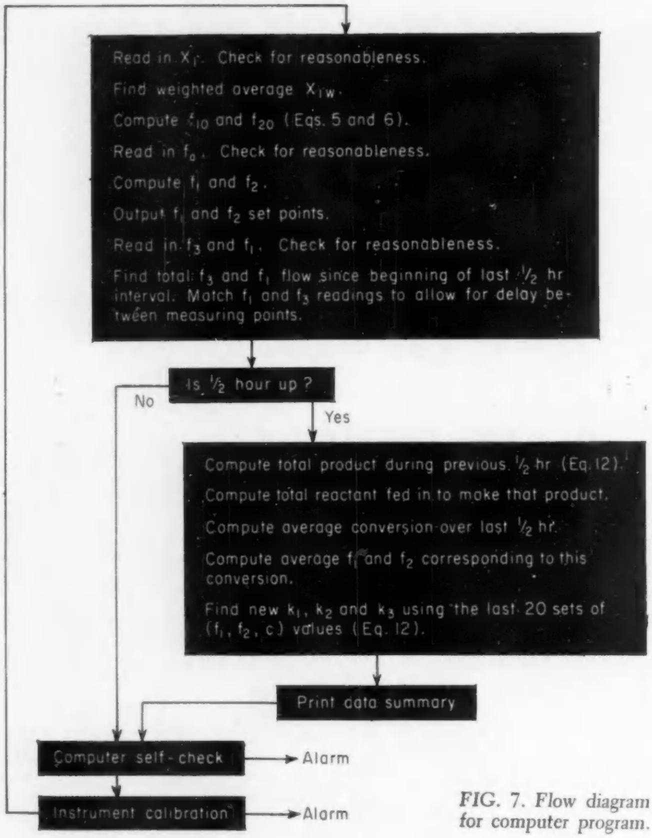


FIG. 7. Flow diagram for computer program.

represented by the single straight line

$$f_1 = f_a \qquad (9)$$

As long as the coordinates of the maximum-profit point lie to the left of and below the lines defined by Equations 7, 8, and 9, the process flow rates f_1 and f_2 should be set at the optimum values f_{10} and f_{20}, Figure 6A. However, if any one of the three inequalities of Equations 2 and 10, namely:

$$f_2 \leqq f_{2\max} \qquad (2)$$

$$f_1 + f_2 \leqq f_{\max}$$

$$f_1 \leqq f_a \qquad (10)$$

is not satisfied, the optimum flow rates cannot always be used. Note that the lines defined by Equations 7 and 8 are fixed, but that the line defined by Equation 9 shifts from time to time as feed availability varies. Furthermore, the coordinates of the optimum point will also shift as x_1 and conversion equation constants k_1, k_2, and k_3 vary.

Some procedure must be specified for enabling the computer-control system to find the best settings for f_1 and f_2 when one or more of the inequalities of Equations 2 and 10 are not satisfied, as in Figure 6B. The procedure to be followed may be based on the fact that, for the simple profit function of Equation 3, the realizable maximum profit will always lie on one of the lines, Equations 7, 8, or 9, if one or more of Equations 2 and 10 are not satisfied. With this in mind, the following procedure may be recognized for finding the proper operating point when the optimum operating point cannot be reached.

(1) If $f_a \geqq f_{max}$:
Find the maximum value of P from Equation 3 along the line $f_1 + f_2 = f_{max}$, with $O \leqq f_2 \leqq f_{2max}$.
Find the maximum value of P along the line $f_2 = f_{2max}$ with $O \leqq f_1 \leqq f_{max} - f_{2max}$.
Compare these two values of P. The process flow rates should be set at the f_1 and f_2 coordinates corresponding to the larger P.

(2) If $f_{max} - f_{2max} < f_a < f_{max}$:
Find the maximum value of P along the line $f_1 = f_a$ with $O \leqq f_2 \leqq f_{max} - f_a$.
Find the maximum value of P along the line $f_1 + f_2 = f_{max}$ with $f_{max} - f_a < f_2 \leqq f_{2max}$.
Find the maximum value of P along the line $f_2 = f_{2max}$ with $O \leqq f_1 < f_{max} - f_{2max}$.
Compare these three values of P. The process-flow rates should be set at the f_1 and f_2 coordinates corresponding to the largest P.

(3) If $f_a \leqq f_{max} - f_{2max}$:
Find the maximum value of P along the line $f_1 = f_a$ with $O \leqq f_2 \leqq f_{2max}$.
Find the maximum value of P along the line $f_2 = f_{2max}$ with $O \leqq f_1 \leqq f_a$.
Compare these two values of P. The process flow rates should be set at the f_1 and f_2 coordinates corresponding to the larger P.

When the digital control system has calculated the appropriate best values for f_1 and f_2, and has taken action to assure that the chosen flow rates are adjusted to the process, it must modify the constants of Equation 4 so as to make sure that the resulting curve is as accurate a prediction as possible of the relationships between conversion, f_1 and f_2. The digital control system does this by taking a measurement of conversion periodically, and relating the measured value to previously set values for f_1 and f_2, taking into account whatever delay exists in the process between the time a flow-rate adjustment is made at the reactor input, and the time the resulting change in conversion is measured. The digital-control system will be required to keep a record of the average of such measurements over the past 10 hours. The computer thus has a list of 20 sets of three numbers each (f_1, f_2, and c) and it must find k_1, k_2, and k_3 such that these 20 points provide a best fit for the resulting curve. If the 20 points are labeled c_i, f_{1i}, f_{2i}, ($i = 1, 2, 3, \ldots 20$) then k_1, k_2, and k_3 may be evaluated by minimizing the following function with respect to the three variables.

$$D = \sum_{i=1}^{i=20}\left[c_i - \frac{k_2 f_{2i}}{1 + k_3 f_{2i}}\, e^{-k_1 f_{1i}}\right]^2 \qquad (11)$$

This is closely related to the self-checking procedure proposed by Case Institute*.

It will be observed that the curve-fitting operation of Equation 11, which is designed to take into account slow and unpredictable changes in the conversion-flow relationship, will be most effective only if fairly wide variations in f_1, f_2, and c occur over a period of 10 hours. Putting it another way, it is meaningless to fit the curve of

* Described in "Process Automation", Report. 1, 1954-56, Case Institute of Technology, September 1956; "Integration of the Computer In Process Control", D. P. Eckman, 11th Annual Instrument-Automation Conference, September 1956.

Equation 4 to a set of 20 points all clustered together in a small area of Figure 3. Such a cluster would occur if, over a period of 10 hours or more, there was little or no variation in x_1, and f_o did not get lower than f_{10}.

One way to avoid this cluster is to require the control system to perturb the process occasionally, if process conditions do not themselves cause a perturbation. In other words, the variables f_1 and f_2 may be set at arbitrary points some distance from their ideal values long enough for the conversion corresponding to those flow rates to be measured. A probably better way is to let the curve-fitting operation depend not only on the 20 most recent process points, but also on previous values of k_1, k_2, and k_3.

The control system whose rough characteristics are now emerging clearly meets process objectives and no limitations on equipment capacity are exceeded. It now must be explained how the necessary process variables are to be measured and controlled, and how the dynamics of the process are to be taken into account.

Specification of components

The principal process variables which must be measured are f_o, the available feed rate; x_1, the percentage of the reactant in the feed; and conversion, which may be computed if x_1 and x_3 are known. There is no difficulty involved in measuring f_o. Flow measuring devices are widely used and are cheap and reliable. The measurement of stream composition is more difficult. There is a continuous analytical instrument available which can measure the concentration of the reactant in the feed stream, but no instrument is available to measure product concentration in the fractionating-tower feed (point 2) or to measure the remaining reactant concentration in that feed.

Product concentration x_3 can be found by measuring the flow rate of material into the fractionating tower and the flow rate at the tower bottom, and dividing the second by the first. This rough value for x_3 may be refined somewhat by noting that the fractionating tower is normally operated so that some fixed percentage of the product appears at the tower top, regardless of tower-feed composition. If, for example, this particular tower is operated so that 5 percent of the distillate-flow rate is product, while approximately 90 percent of the residue is product, then x_3 can be found as follows:

$$f_1 x_3 = 0.05\,(f_1 - f_3) + 0.9 f_3$$

$$x_3 = 0.9\frac{f_3}{f_1} + 0.05 \qquad (12)$$

where f_3 = flow rate of product from fractionating system, and

f_1 = tower-feed rate

So far, no mention has been made of the frequency with which measurements and computations are to take place. It is now necessary to specify these frequencies and to discuss how they will react on the control system and on the process. First, adjustments will be made in f_1 and f_2, as often as it is possible to measure the reactant concentration, and to carry out the calculations necessary to find f_1 and f_2. These calculations are not dependent upon measurements made later in the process, and there can therefore be no instability due to feedback. The modifications to Equation 4, on the other hand, will be carried out much more infrequently and will be based upon data accumulated over a long period of time. Specifically, one value of conversion will be obtained every half-hour by averaging instantaneous samples of flow rates and of reactant percentages over that period of time. To each value of conversion so obtained, appropriate average value of f_1 and f_2 will be determined. These three numbers, together with the corresponding numbers for the 19 previous half-hourly intervals, are employed in Equation 11 to determine k_1, k_2, and k_3. Adjustments in these k values thus take place very slowly, being affected only by data obtained over a long period of time. It is at this point that feedback is introduced into the control system. However, the feedback is smoothed and delayed to such an extent that it will not upset the dynamic equilibrium of the process.

With the control system thus roughly outlined, it is possible to evaluate cost and potential payoff. The cost depends upon the cost of the computer, analog-digital converters, and associated instrumentation, and the payoff depends entirely on a comparison of the control actions taken by operators in the past with the results which would have been obtained if the digital-control system had been operating on the same feeds, or on the feeds expected after the installation of such a control system. For large flow rates and valuable materials, a deviation from optimum control for one hour may result in \$100 of lost profits. The exact dollar loss depends, of course, on how peaked the profit curve is at its optimum point and how far away from that point the process operates. Depending on the parameters involved, the profit curve may have a very flat peak, so that the system is fairly insensitive to variation in f_1 and f_2. This sensitivity must be evaluated in determining payoff.

The principal control system components required are a new instrument for the measurement of x_1, the reactant composition, and the digital control computer itself. The system designer's study of the required computer program must be extensive enough to allow him to specify computer precision, speed, and memory

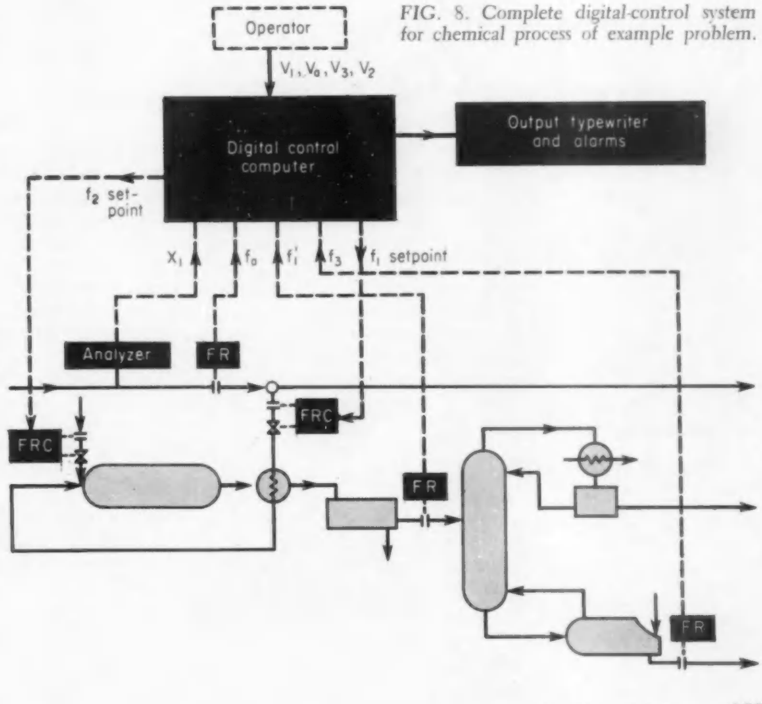


FIG. 8. Complete digital-control system for chemical process of example problem.

capacity required. The number and type of input and output transducers and lines must also be specified.

System operation

A flow diagram for the computer program is shown in Figure 7, and the entire control system is displayed in Figure 8. Note that care must be taken in evaluating measurements made on the process to take the process delays into account. For example, the product concentration x_s of Equation 12 is evaluated by employing two readings, f_s and f_1, which occur 45 min apart. This means that every time this quantity is evaluated, the latest reading of f_s is compared with the value of f_1 measured 45 min earlier and stored in the computer. At that same time, the latest measurement of f_1 is stored away for use 45 min later. Note that the computer checks itself and calibrates the continuous analytical instrument used to measure x_1 during every computer cycle. Furthermore, it prints a summary of the pertinent operating data every half-hour. This summary includes the average values for x_1, f_1, f_2, x_s c, and f_e. In addition, it may be desirable to print out the maximum and minimum of values for f_e during the previous half-hour.

The instrument readings taken at various points in the process are important to the correct control of the process, and instrument malfunctions can and do cause serious troubles in process control. In a conventional process, the operators are told what to look for on the control panel in the way of instrument failures. These same instructions can be given to the computer, which will print an alarm warning the operator when some failure occurs.

The rules for detecting a failure depend on the characteristics of the instrument being checked and upon the characteristics of the quantity being measured. For example, it may be that the feed for the unit is varying in composition almost continuously, but that reactant concentration never is less than 40 percent or greater than 60 percent. To check the operation of the continuous analytical instrument, then, the computer might compare each reading for x_1 with the previous two readings, and print out an alarm if all three of them are the same, since it would be very unlikely that three sequential readings would be identical. The computer might also check each reading to see that it lies within the range of 40 to 60 percent, and print out an alarm when this range is exceeded. The alarm would identify the suspect instrument, and would indicate what seemed to be the trouble with it. These instrument checks are indicated in Figure 7 as "checks for reasonableness".

Computer malfunctions detected by the program also cause an alarm to be given. The operator must then disconnect the computer outputs so that controller set-points are set manually; the operation of the process then deteriorates to the conditions which existed before the introduction of a digital-control system. The operator must also be on the lookout for computer errors which are not detected by the computer itself. The computer may, for example, print out nonsense; it may try to adjust process variables to impossible values; it may try to read information through the input device for no reason; or it may stop unexpectedly. Each of the possibilities must be anticipated, and their possible effect on the control system evaluated and compensated for by the system designer.

Several additional comments must be made about the proposed control system. A practical control system would probably control variables other than the flows f_1 and f_s. There might, in general, be some advantage to be gained from controlling reactor temperature and pressure, or fractionating-tower conditions, and the effect of these variables can be reflected in a profit equation similar to Equation 3.

The control system should be arranged so that the effect of other process variables on conversion can be analyzed and logged as time goes on. If the effect of some other variable—the character of the catalyst or the content of the inert part of the feed—does have an effect, that effect can be incorporated into the control system by providing the appropriate input data and rewriting the computer program to use that data.

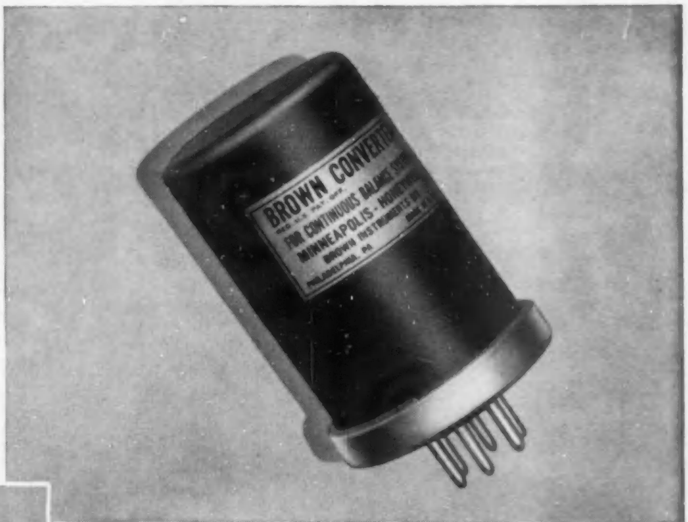
Eugene M. Grabbe

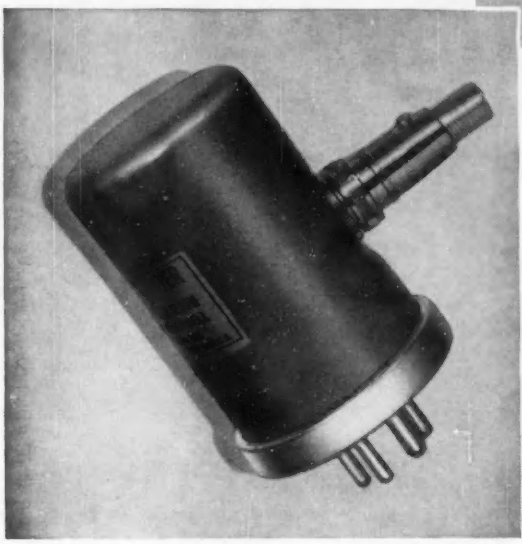
Montgomery Phister Jr.

We rank one of the authors in the "needs no introduction" category. He is Gene Grabbe, senior staff consultant on automation in the Computer Systems Div. of The Ramo-Wooldridge Corp. The editor of a brand new Wiley book *(Automation in Business and Industry)*, Gene is both a CtE contributor and one of our consulting editors. Just a few months back, we sketched his life and career in a *Control Personality* (CtE, February '57, p. 23).

Gene's co-author Montgomery Phister Jr. is head of the Industrial Control Systems Section of R-W's Computer Systems Div. His work has centered about digital computers including logical design, maintenance techniques, scientific and business applications, and systems planning and analysis. The latter has prompted Monty to encourage the use of electronics in the automatic control of industrial processes.

Well-qualified scholastically for his field with BS and MS degrees in electrical engineering from Stamford University and a PhD in physics from Cambridge University, Monty has often been seen on the campus of UCLA in the role of a visiting assistant professor of engineering.





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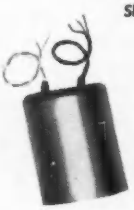

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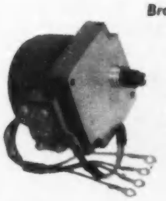

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First in Controls

A Simple Noninteracting Three-Term Controller

A new circuit that can produce true unity integration for periods of 30 min and more permits construction of a very simple three-term electronic controller with no proportional, derivative, or integral interaction.

F. STEGHART
Consultant, London

It is curious that in spite of the great progress that has been made in all fields of electronics the only known noninteracting controller uses the servo principle and is, therefore, comparatively complicated.

A controller with no moving parts was described at the Heidelberg Conference[1]; it required nine amplifying tubes and two neon regulating tubes without the preamplifier. Analysis of this problem of complexity shows that the greatest difficulty is in the design of a simple and accurate integrator. Many papers on the theory and practice of such integrating circuits exist, and it has been proved that unity of integration is theoretically possible[2]. Korn and Korn[3] state, however, that little is known about practical applications and Dr. d'Ombrain's paper[1] indicates that unity of integration cannot be achieved with a bootstrap integrator.

Theoretically correct differentiation is impossible, because for infinite frequencies infinite amplification would be necessary. Theoretically perfect integration, however, is possible without infinite amplification, but has not been achieved in existing designs because grounding and insulation problems could not be solved.

Figure 1 shows a circuit which transforms theory into practice. By passing a current through the resistance R_t, a voltage E_t is developed which causes the current to flow through resistance R and to charge capacitor C. A small resistance R_{comp} is inserted in this circuit. The voltage on the capacitor controls the pentode tube V, in whose output the regulating unit and a small magnetic amplifier is inserted. The output of the magnetic amplifier feeds the resistance R_{comp} and produces in the integrating circuit a compensating voltage which is equal and opposite to the voltage on the condenser. The accuracy of the integration in the controller to be described is plus or minus 0.25 percent. By means of this new integration it is possible not only to integrate at unity, but, depending on the design of the integrator, to go slightly below and beyond it and thereby optimize the characteristic of the integration.

The great simplicity and accuracy of the new integrator gives it considerable advantage not only in three-term controllers but in analog computers, etc., as well.

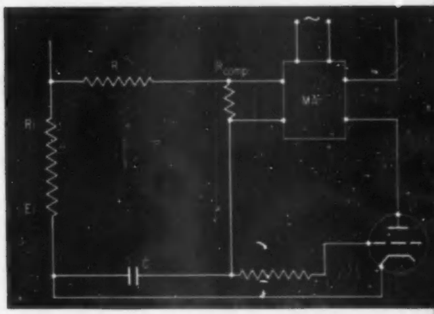

FIG. 1. Part of output is fed back to compensate counter-voltage on integrating capacitor to produce unity integration.

Noninteracting controller

Figure 2 shows its application in an automatic controller. The left side of the diagram shows the measured value (MV), a reference supply regulated by an argon tube A, and an adjustment for the desired value (DV). Tube V_1 passes the current proportional to difference between the meas-

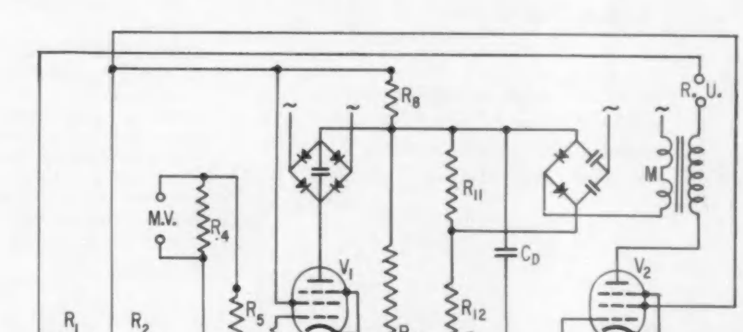

FIG. 2. Noninteracting three-term controller uses saturable reactor type of magnetic amplifier for feedback.

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ured value and the desired value through the resistance R_9.

If the measured value changes, then the current through resistances R_9 and R_{10} changes, and the voltage of the resistance R_9 begins to charge or discharge capacitor C_1. The voltage across C_1 is the integrating element in the grid circuit of tube V_2. Resistance R_{10} supplies the proportional action element, and the active part of the resistance R_{18} the derivative action element. The three voltages are added in series in the grid circuit of V_2, which supplies the output current of the controller. This current flows also through the magnetic amplifier *M* and all three functions are, therefore, fed back degeneratively.

The fed-back integral value serves to compensate the capacitor counter voltage; the fed-back proportional value eliminates error in the proportional output; and the fed-back derivative value is nil after a step function has passed through the controller since the charging time equals zero. In the present design, even a strong and permanent error produces from the derivative feedback only a very small and temporary change of the integral-action element, and even this small change disappears after a reversal of the derivative action.

Models of this controller prove that it works as close to the theory as can be required. Resistance R_9 is made ten times the value of R_{10} to make the feedback through the magnetic amplifier and the temporary error from the feedback of the derivative element insignificant. The input of the controller has been made 0-30 ma dc, since this higher value is considered preferable to the lower values that seem to have become general practice in the United States. Currents of 30 ma can be integrated by dc motors very simply, whereas values of only 5 ma cannot. The output of the controller is 3-15 ma dc, and it can work into a load resistance of 4,000 ohms.

The three elements are practically noninteracting: the proportional action range is 4-300 percent; the integral action, 0-30 min.; the derivative action element, 0-5 min. The allover accuracy of the controller is plus or minus 0.5 percent, including line fluctuations of plus or minus 10 volts.

The magnetic amplifier is a simple saturable reactor type, and measures 7.5 cm x 5 cm x 2.5 cm. A model with a separate amplifier for flow measurement with manual control and a profile indicator has been built that occupies 10 cm x 12.5 cm on a panel and is 25 cm deep.

A simplified design

The reason for the success of the circuit just described is that the feedback from the output of the amplifier is highly insulated from the RC circuit in the forward loop. Instead of magnetic amplifiers here, it is possible to use a current transformer, as shown in Figure 3. The input of this controller is completely isolated from the output. This is particularly important for temperature control when the preamplifier is not insulated from the controller input.

A current proportional to the measured value is passed through terminals A and B and resistances 1 and 2. As before, the voltage across resistance 2 produces the proportional element, the voltage across capacitor 3 the integral action element, and the voltage across the active part of resistance 4 the derivative action element. Integral capacitor 3 is charged by the voltage across resistance 1 and the time constant is produced by high resistances 5 and 6.

The plate voltage for pentode amplifier 7 is obtained from winding 8 on power transformer 9 and rectified by bridge rectifier 10. With this arrangement the ac current in winding 8 is directly proportional to the plate current of tube 7.

A current transformer, 11, is connected on the ac side of the rectifier. Its output voltage is directly proportional to the plate current of tube 7, and is rectified by rectifier 12 and introduced into the capacitor charging circuit across resistor 13. Thus, the plate circuit of tube 7 is isolated from the RC integral circuit.

The output of the correcting unit must always be proportional to the plate current of tube 7. In this instance resistance 14 completes the plate circuit, and the voltage to drive the correcting unit is obtained from another transformer, 15, also connected to the ac side of the rectifier 10. The output of this transformer is also rectified, producing a dc voltage across the output terminals *C* and *D* proportional to the tube current.

Winding 18 on the power transformer supplies rectifier 17, which is regulated by argon tube 16, as a supply for the screen grid of tube 7. Resistors 19 and 20 provide a regulated grid bias for the tube. The plate current of a pentode with a regulated screen supply remains constant over a very wide range of plate voltage, so that changes in the load impedance will not affect the plate current. A reasonable load may therefore be taken through transformer 15 without noticeably affecting the linearity of the controller.

The author expresses his thanks to his assistant, Peter Kershaw, who is a coinventor of the first controller.

U. S. Patent Application 538,498; Oct. 18, 1954.

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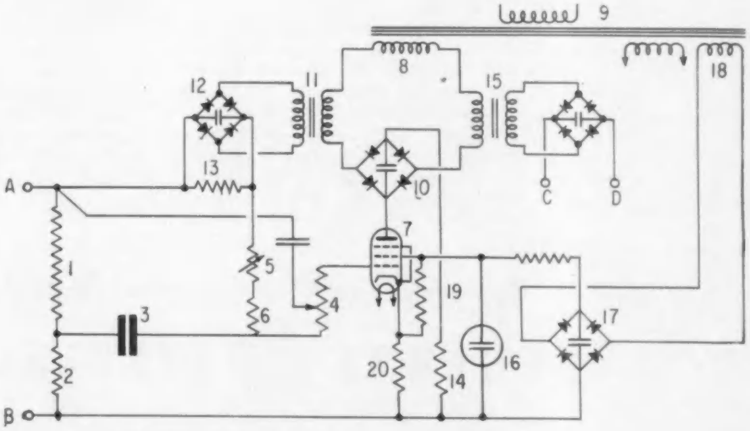
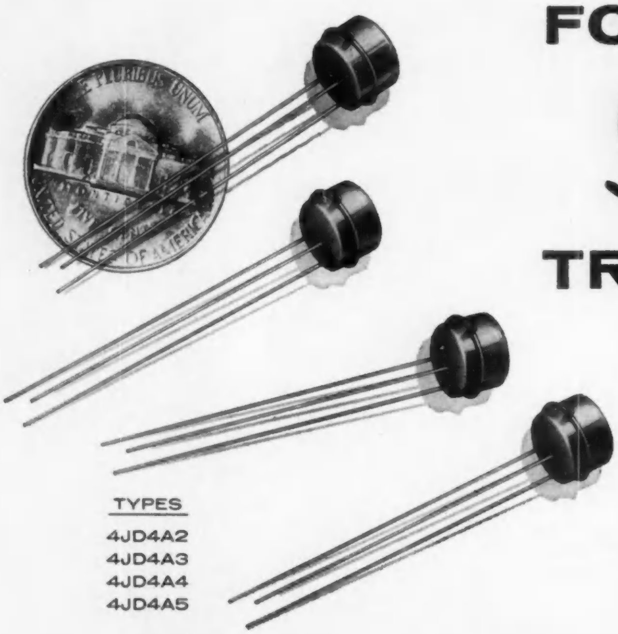


FIG. 3. Simplified circuit feeds back via current transformers, offers complete isolation between input and output.



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E. S. SHEPARD SR.
AiResearch Co.

The idea for the "magnetic-spring accelerometer" was born in 1948 when the author, as a member of the Boston College expedition to the Greenland Ice Cap, was responsible for the development of instruments that would work efficiently at temperatures down to minus 70 or 80 deg F. The idea was never tried until the AiResearch Co. used it in 1953; it is now assigned to AiResearch.

The low-temperature environmental conditions in that problem required an accelerometer that had no metallic springs, hinges, or pivots, and no damping fluid. The unit also had to be reasonably small and still have a low resonance, and needed a zero calibration adjustment. Its output could be either a variable resistance or a self-generated voltage.

These requirements are met by using the opposing fields of permanent magnets as the elastic system. The construction of the magnetic-spring accelerometer can be seen in the photograph of Figure 1 and the drawings of Figure 3 and Figure 4. The outboard bearings guide the moving magnet and prevent its "falling out" when the accelerometer is not vertical. The opposing fields have little centering effect on the moving magnet, so that the outboard bearings are needed even in a vertical position.

Theory of operation

Any seismic mass accelerometer has the same frequency characteristic as a second-order high-pass filter, Figure 2. For frequencies far enough above the natural resonant frequency of the sprung mass, positional displacement of the seismic mass relative to the frame of the accelerometer is directly proportional to acceleration of the frame. The lowest useful frequency is limited by the resonant frequency f_r, and, for any given f_r, by the damping between the seismic mass and the frame. In the magnetic-spring accelerometer damping is electromagnetic.

The magnetic-spring accelerometer can also generate its output electromagnetically, and its sensitivity is very high in this form. If pickup coils are wound around the two stationary magnets, voltages are induced in these coils that are proportional to the velocity of the moving magnet. As the moving magnet moves closer to or farther from the stationary magnets, it increases or decreases the reluctance in their flux paths, causing a variation in the flux linking the coils. This affect is nonlinear with respect to amplitude for either pole face considered separately, but the push-pull arrangement of the magnets and the coils linearizes the output. The coils must be connected series-aiding.

Since the voltage across the coils is proportional to the velocity of the seismic mass, electromagnetic damping can be added simply by connecting a low resistance across the output. This causes a current to flow in the coils, producing an alternating magnetic flux that leads the motion of the mass by about 90 deg, and thus acts

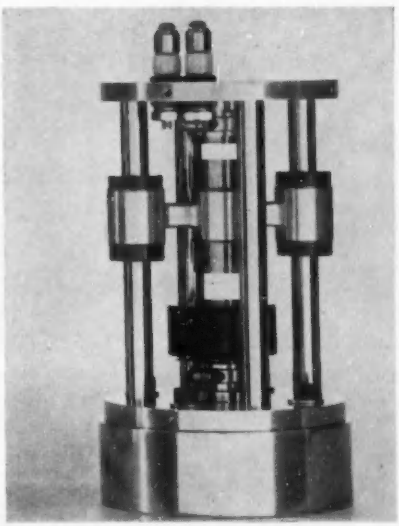


FIG. 1. Magnetic-spring accelerometer. Unit is 4 in. high; smaller version can be built.

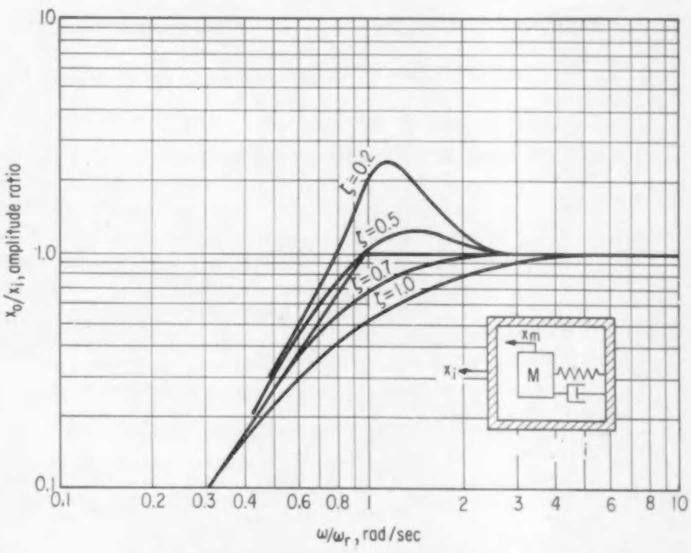
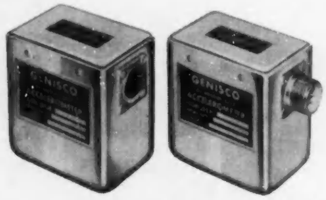


FIG. 2. Frequency characteristic of seismic-mass accelerometer. Above ω_r, output x_o is proportional to acceleration d^2x_i/dt^2.



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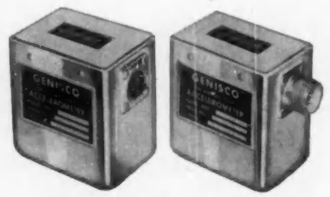

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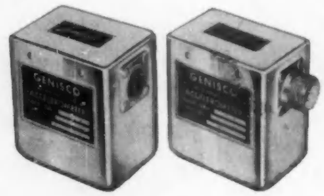

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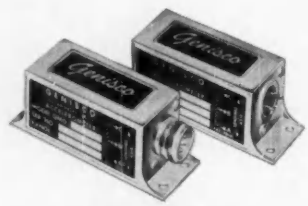

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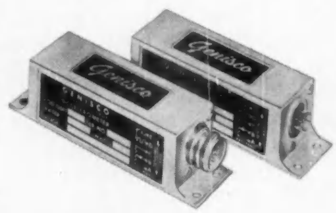
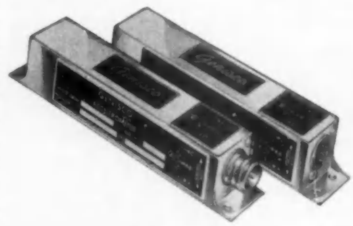


Model GMT

Basically a Model GMO with internal thermostat-operated heater, assuring maximum environmental stability within the instrument. Damping remains constant with change in ambient temperature.



Model GDM

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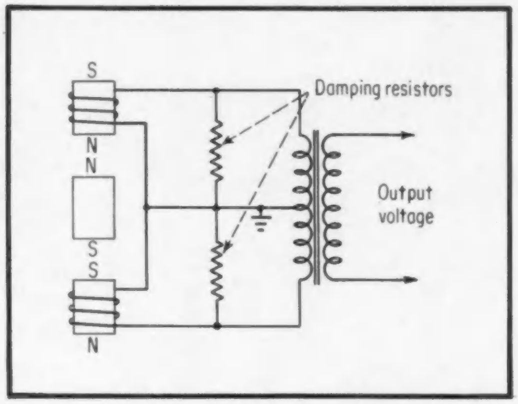


FIG. 3. Output circuit for highest sensitivity uses self-generated signal from coils on stationary magnets.

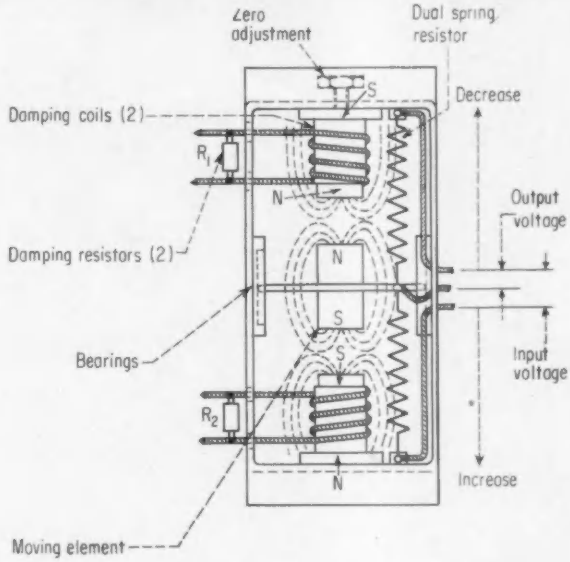


FIG. 4. Schematic arrangement of magnetic-spring accelerometer with spring-resistor output.

as viscous damping. The damping is controlled by varying this resistance.

It was stated earlier that the positional displacement of the mass with respect to the frame is proportional to acceleration. The output of the coils on the stationary magnets is proportional to the velocity, or the first derivative of the displacement of the mass. Hence, the output need only be passed through a single integrating time constant with a break frequency low compared to the accelerometer's resonant frequency.

The output of this circuit is directly proportional to the absolute acceleration of the accelerometer frame.

The accelerometer pictured in Figure 1 is relatively large, but could be made in smaller sizes. The one pictured weighs about 10 to 12 oz. Its natural frequency can be varied between 3 and 100 cps by a screw adjustment of the spacing of the stationary magnets, and by using stronger or weaker magnets. Damping can be made optimum for any natural frequency by adjusting the damping resistance. The accelerometer will operate over a temperature range from minus 100 to plus 250 deg F, and is very sensitive to small accelerations.

Linearity errors have been less than ¼ percent of full-scale output, and zero drift has been less than 0.04 percent, with an overall accuracy of ½ percent. Output due to accelerations perpendicular to main axis is less than 0.2% of fullscale output.

Note that with a moving mass weighing only 5 grams it is possible to obtain natural frequencies as low as 10 to 16 cps. It is also possible to record the output of this accelerometer without amplification.

Simulate Transport Lags With Magnetic Tape

Transport lag or dead time in processes presents a difficult simulation problem, and many solutions have been proposed. Here's a simple one that can give very accurate results, even if the dead time is dynamically variable.

D. C. REUKAUF
Minneapolis-Honeywell Regulator Co., Davies Laboratories Div.

Correct analog-computer simulation of transport lags common to process industry operations is important for control system studies, because these dead times are often several seconds long or more, and severely affect the dynamics of the system. Most methods described previously have involved approximations using several analog-computer amplifiers.

In the simulation problem for which the delay unit to be described was built, the temperature change in a fluid in a pipe due to one heat exchanger did not appear at a second heat exchanger until the fluid reached it several seconds later. The fluid was then returned to the first heat exchanger by a second pipe to form a closed system. The simulation needed two temperature channels of about the same delay time, and the ability to change the relative delay between them so as to try different pipe lengths in the two halves of the loop.

The resulting unit is shown in Figure 1. A magnetic-tape-loop mechanism with a variable speed drive is servo-controlled by the analog transit-time voltage. In the heat exchanger application, the transit-time voltage is directly proportional to pump speed. The distance between a recording head

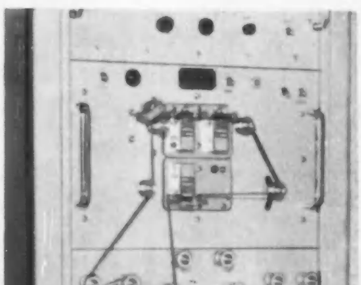
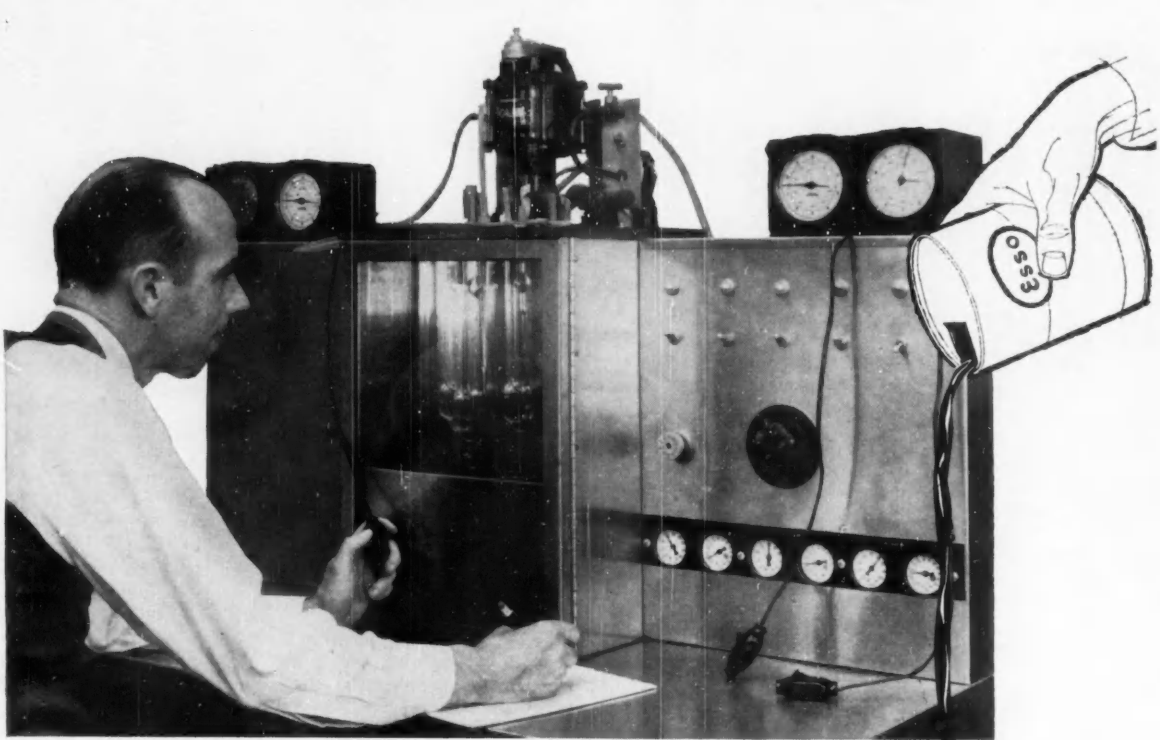


FIG. 1. Transit-time simulater. The space on the playback-head mounting plate can accommodate an additional playback head if the delay on our track is to be variable with respect to the delay on the other.



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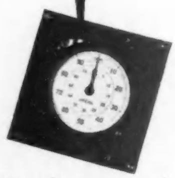

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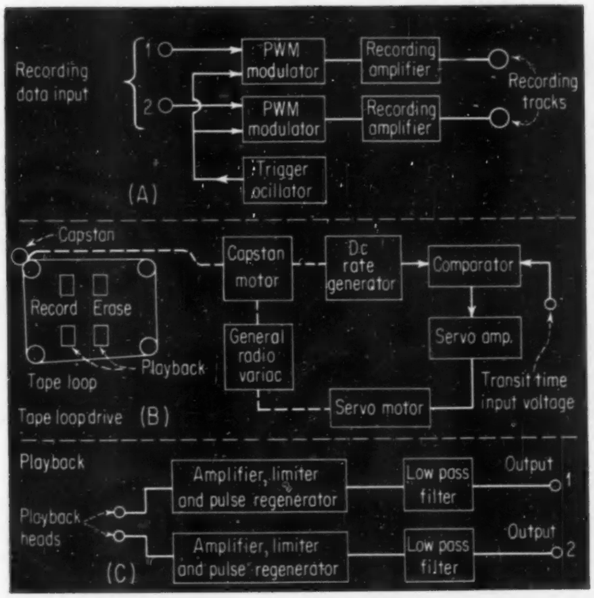


FIG. 2. Transit-time simulator. A—data recording channels; B—tape speed servo; and C—playback circuitry.

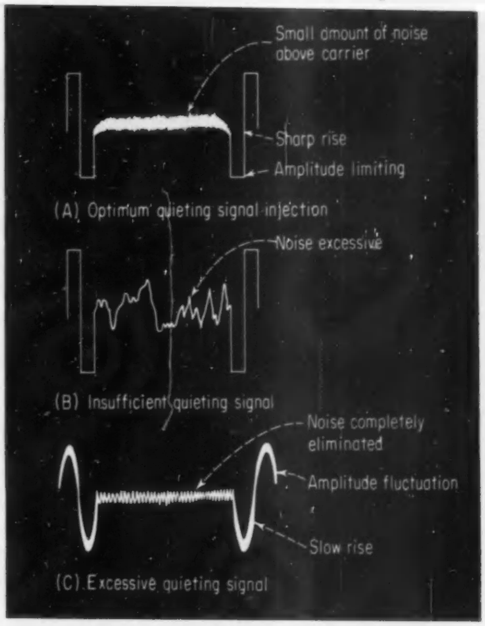


FIG. 3. Output of limiting amplifier, showing effect on signal of various output levels of quieting oscillator.

and a playback head causes a delay between recording and reproduction which is inversely proportional to tape speed, and thus to pump speed. An erase head clears the tape just before it reaches the recording head.

The principal difficulty encountered in any magnetic-tape-recording system is the variation in velocity of the tape across the recording and playback heads caused by imperfections in the transport mechanism or tape. These speed variations affect the accuracy of the reproduced signal in that both the amplitude and frequency are varied at a rate corresponding to the wow and flutter components. Substantial reduction in these components can be obtained by careful design and construction of the tape transport and its component parts, but a point is reached where this is uneconomical or impractical, and additional improvement must be sought in special recording methods.

Pulse width modulation

Pulse width modulation (PWM) was found to be the best recording technique.

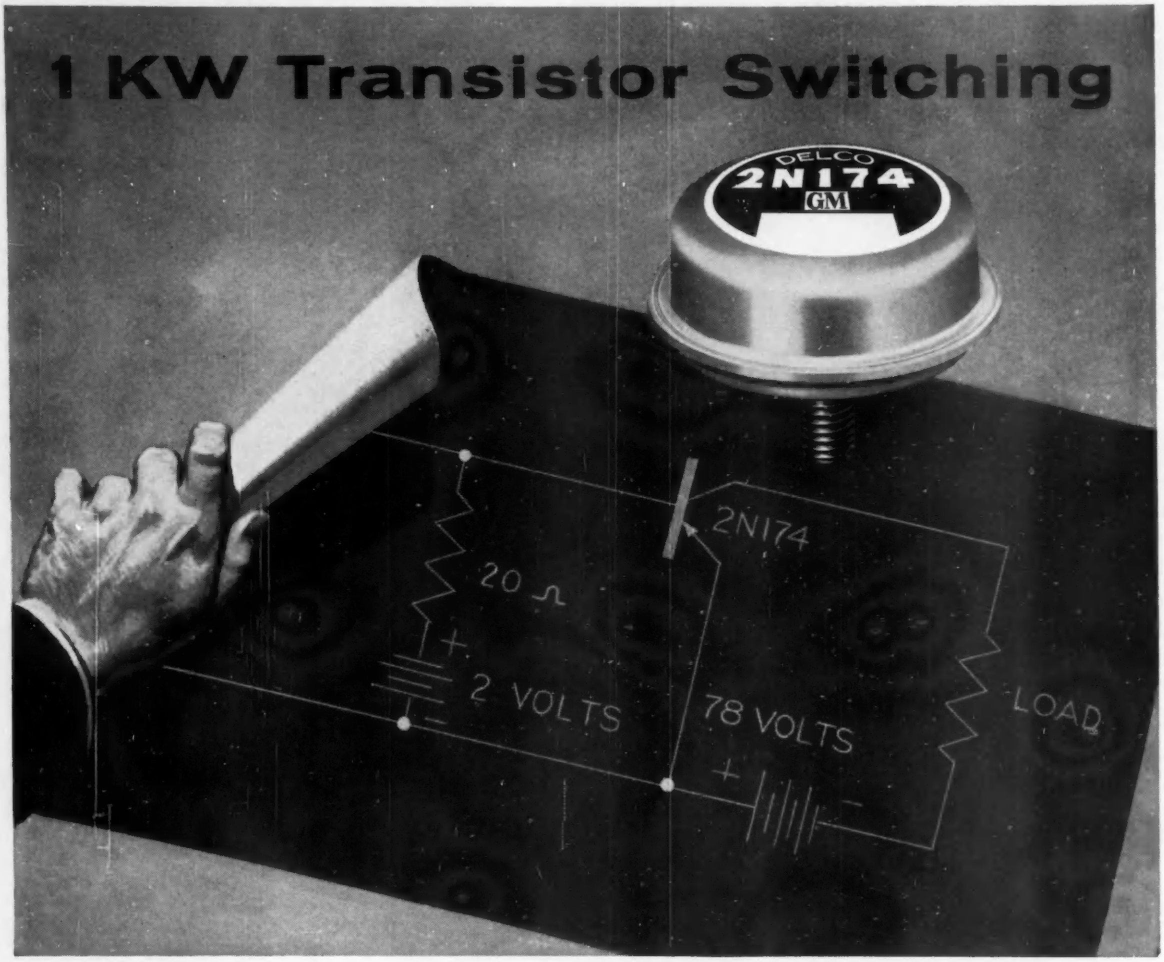
A PWM signal carries intelligence by variation of the duration of a pulse, which is repeated at fixed time intervals so that the average voltage over a reasonable number of pulse periods will reproduce the modulating signal. If the pulse period is short enough so that the averaging of a number of pulses does not require too long a time, the actual period is unimportant and does not affect the average value of the data signal. Consequently, within reasonable limits, the variations in pulse-repetition rate caused by tape-speed changes will not affect the data signal output i.e., the pulse width varies by the same ratio as the pulse period and the average level is not changed.

A block diagram of the complete system is shown in Figure 2. The tape-loop mechanism uses a two-phase servomotor for the source of capstan power. The setting of the Variac on the control field, which is regulated by the transmit time voltage, determines the tape speed. The recording system is relatively simple. An oscillator triggers the variable pulse width generators (phantastrons whose plates are amplitude-modulated, producing the PWM signal at the screen grids). Satisfactory recording on tape necessitates differentiating these pulses and recording only the sharp spikes. This is accomplished in the PWM recording amplifier.

The playback unit reads the sharp pulses from the tape, and by suitable circuitry recovers the original PWM signal with the amplitude of the pulses carefully limited to maintain a constant value. The original data signal is then recovered by passing the pulse train through a suitable low-pass filter.

A unique feature of the playback system is the quieting oscillator (part of the limiter). It is well known that a high-gain-limiting amplifier in the absence of an input signal has a high noise level at its output. Since the signal recovered from the tape on playback is in the form of pulses indicating the leading and trailing edges of the PWM pulses, it is evident that during the time between pulses the amplifier has no input signal and the noise rises to a high value. Using this amplifier to drive the Eccles-Jordon flip-flop pulse regenerating circuit would cause spurious triggering and a resultant high noise level or distortion at the output. This condition is remedied by injecting a 2-mc. signal at the input to the limiting amplifier. Now, with an oscilloscope connected at the output of the limiting amplifier and the desired PWM signal injected at the input to the preamplifier, the level of the 2-mc. signal can easily be adjusted to the point where the noise between PWM pulses is greatly reduced and little or no degradation of the desired signal is noted. The quieting signal has no effect on the Eccles-Jordon trigger circuit because the level is too low and the frequency too high to cause spurious triggering. Figure 3 shows the conditions at the output of the limiting amplifier with varying levels of quieting-signal injection.

The equipment delivers the temperature analogs back to the computer with an accuracy of plus or minus 1 percent of the input signal. The tape speed follows the delay analog voltage with an accuracy of plus or minus 2 percent. Dc drift at the output of the system was 0.25 percent of full scale over a 30-min period after allowing a 1-hr warmup. The PWM playback amplifier has been found useful in many other applications for accurate, stable pulse regenerating.



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Controls for the Boiling-Water Reactor

The power-level control rods on the Experimental Boiling Water Reactor at Argonne (CtE, April, p. 23) are adjusted manually because the reaction is very stable and the rods need to be moved only a fraction of an inch in several hours. The balance between steam and feedwater flow rates is critical, however, and these control systems are described here.

J. M. HARRER
Argonne National Laboratory

In a boiling reactor the reactor steam output is a function of rod position. The actual reactor heat or neutron flux power is very sensitive to two system parameters: steam flow and water flow.

Water enters into the nuclear reaction as a neutron moderator and reflector. Absorber rods of hafnium add a positive reactivity as the absorber is removed. This forces the core to put out enough heat to form voids in the fuel elements and to reduce water density sufficiently so that the negative reactivity created just exactly offsets the rod movement.

If the rate of steam flow is constant, void formation is quite regular and reactor power remains nearly constant. If, however, steam flow changes, the increase of voids in the core makes the reactivity more negative than called for by the rod position, and the heat or flux power falls. This effect frequently is called "the positive feedback effect" in boiling reactors. If the turbine admission valve were opened to raise the turbine load, the reactor flux would fall. Since the disturbance and the result are in the same direction, the effect is that of positive feedback.

Also, under steady-flow conditions the mass flow of feedwater into the reactor must just equal the mass flow of steam out of the reactor. Lacking this equality, the water level would rise or fall. The heat or flux power is not very sensitive to water-level changes of a few inches, so accurate level control is not vital. However, the water enters the reactor at about 100 deg F and reaches about 478 deg F before steam is formed. This water-heating process requires about 35 percent of the heat output of the core.

It follows that if the water input is higher than the steam output of the core, the heat power would have to be still higher to maintain a constant void-content in the fuel elements.

Thus, it is clear that even though the EBWR power output is constant at a constant rod position for periods of several hours, rapid changes in steam flow or water flow could change the heat or flux power over quite a wide range. For this reason, steam flow and water flow are automatically regulated, while rod positions are changed manually by the reactor operator. Under steady conditions, the operator must move a rod only a fraction of an inch in several hours. This movement is dictated mainly by an increase in fission products which absorb neutrons, and (to a much lesser extent) by fuel depletion.

Steam-flow control

Figure 1 is the basic steam-flow control schematic. The reactor pressure is impressed on one side of a bellows and opposed by a spring force. The spring tension is adjustable from the control room console by a motorized lever. The difference $P\text{-}P_o$ at point 1 in Figure 1 is obtained by an Askania type regulator and converted by servo action to an oil pressure. A constant is applied to determine the amount of valve movement which will result from the pressure error $P\text{-}P_o$. This passes another differencing unit, point 2 on Figure 1, and if the negative signal is zero at this point, the valve position is proportional to the total error $K\ (P\text{-}P_o)$.

Thus, as pressure rises, the valve opens, and at some pressure P, not necessarily the 600-psig rated for the reactor system, the dP/dt becomes zero because the steam flow to the condenser is exactly that required to remove the reactor heat. To raise pressure (or lower it), the operator adjusts the remotely-controlled value P_o. When the desired pressure of 600 psig is obtained, the system contains a memory value $K\ (P\text{-}P_o)$. The function of this retained signal is next described.

When the turbine valve is opened to adjust for a change in load on the turbine, a signal of valve position passes through difference device 3 in Figure 1. The negative signal at point 3 is zero if the turbine trip valve, which protects against turbine overspeed, is open. If it is not open, the

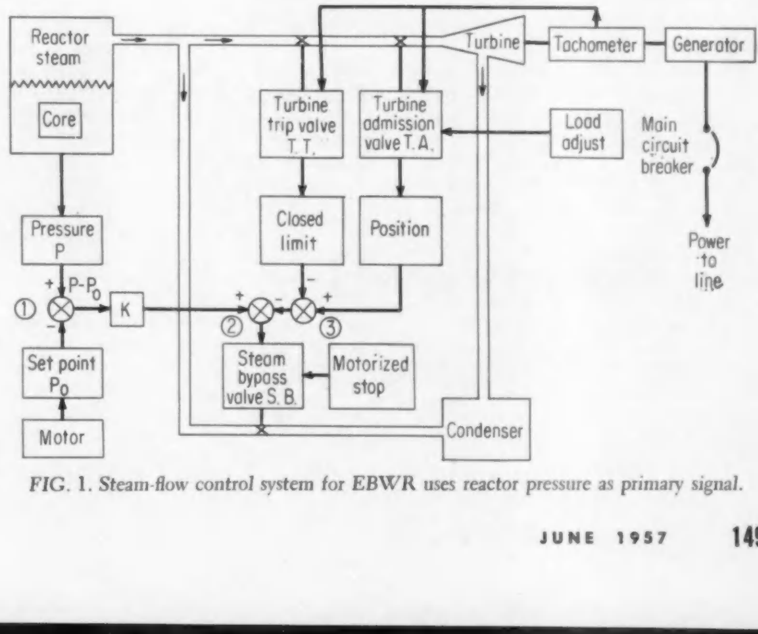

FIG. 1. Steam-flow control system for EBWR uses reactor pressure as primary signal.

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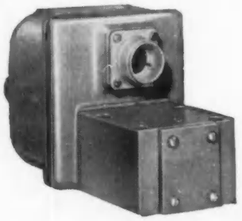
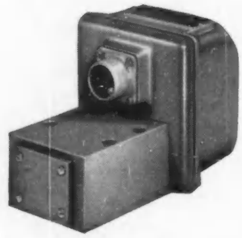
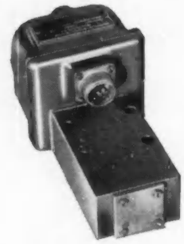
Flow Specifications for Typical Individual Valve Models



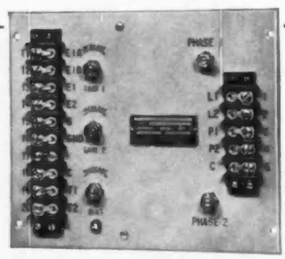
3-Way Valve (XVJ300)
Output Flow (no load)
100 psi—3.5 gpm
1000 psi—9.9 gpm



3-Way Valve (XVJ302)
Output Flow (no load)
100 psi—2.0 gpm
1000 psi—6.0 gpm



4-Way Valve (XVJ303)
Output Flow (no load)
100 psi—1.5 gpm
1000 psi—5.0 gpm



Amplifier (XRJ301)

Transistor Servo Amplifier. High gain, multiple input amplifier with superior reliability . . . Drives electro-hydraulic servo valves, d-c relays and small d-c servo motors up to 5 watts . . . Weight: 5 lbs. . . . Voltage and Frequency: 115 volts, 60 cps. . . . Power consumption: 20 watts . . . Input Impedance: 10,000 ohms . . . Load Impedance: 50 to 1000 ohms . . . Sensitivity: 1 mv input signal produces differential current of 15 ma in a load of 70 ohms, with maximum gain . . . Maximum Ambient Temperature: 135° F.

signal passing the difference device at point 3 is made zero.

In this way, a signal reaches the differencing device at point 2, which can partially or wholly cancel the K $(P\text{-}P_o)$ signal. Thus, as the turbine admission valve is opened, the steam by-pass closes. If either the turbine admission valve or turbine trip valve closes, the by-pass valve opens, i.e., returns to a position determined by the setting K $(P\text{-}P_o)$, which remains in the system as a memory value.

In practice, the value of K is set so that a $(P\text{-}P_o)$ of 25 psig opens the by-pass valve enough to pass 60,000 lb/hr of steam. The system has been quite satisfactory and reliable in service, although detailed performance data have not yet been analyzed.

The premise of the entire system is that if the supply oil pressure for control fails, the by-pass valve closes. This was determined to be the safest method, because rapid blowdown of reactor pressure, due to a wide-open by-pass valve, could result in thermal stresses to the reactor pressure vessel and in a drop in reactor-water temperature, the latter producing a positive reactivity. The motorized stop, which limits the amount by which the valve can close, is held in practice close to the position that the valve holds while in control, thus limiting the rate at which the pressure can rise.

As described before, the water-input rate must equal the output-steamflow rate. An additional criterion was added for this plant because the boiling reactor is so sensitive to water-flow rate. An induction motor drive on the control valve limited the rate of change of water flow to 600 lb/hr/sec.

The system is shown in Figure 2.

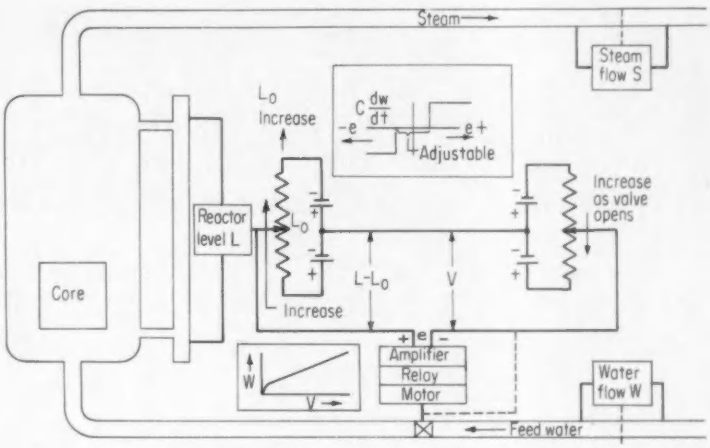


FIG. 2. Feedwater control system measures reactor water level and valve position to control rate of change of flow.

Reactor level is measured by a differential pressure cell (Manning, Maxwell & Moore), in which the signal is converted to electrical current by force balance in an electronic oscillator circuit (Microsen). The output signal is displayed at the control room by a Leeds & Northrup Speedomax recorder-controller. The L_o potentiometer of Figure 2 is mounted in this instrument and is moved by turning a pointer on the front of the controller. A second potentiometer is connected to the valve-stem proper. As the level L falls below the setting L_o, a positive error e is obtained, which causes the input water flow to increase at a fixed rate. Negative signal for cancelation of e is obtained as the valve stem moves. The system equation becomes

$$e = L - L_o - V$$
$$V = K_1 W$$

where the symbols are as shown on Figure 2. Thus when $e = 0$

$$W = \frac{1}{K_1}\left(L - L_o\right)$$

Even though the level changes with load, the system seeks the control point in which the rate of change of level is zero. It is evident that this can only be reached if the water flow equals the steam flow. The value of $L - L_o$ for $W = 60{,}000$ lb/hr is set at 7 in. The amplifier which controls the motor relays is a standard Leeds & Northrup position-adjusting control unit, Series 50.

A more complex system, using automatic reset that matches steam and water flow directly, is normally called three-point control in power-plant practice. To-date, the more complex system has not proved as satisfactory as the simple system just described.

Transistor-Controlled Carbon-Arc Light

A searchlight seems a strange place to find transistor amplifiers and servomotors, but in a new focusing and recarboning system developed by ARMA Div. of American Bosch Arma Corp. for Navy airborne searchlights there are transistors and a photodiode. The searchlight involved is the most powerful airborne light being made today. Its maximum light output is 130 million candlepower.

The searchlight is mounted in gimbals below the airplane's wing and remotely positioned by servomotors either manually from a pistol-grip control or automatically from radar azimuth and elevation computers. The arc current is about 180 amp dc at 75 volts. A crater formed by the positive carbon as it burns is kept symmetrical by slow rotation of the carbon. The carbon burns at 35 in. per hr, and the crater must be kept at the focal point of the main reflector.

When the crater is at the focal point, a small reflector is set so that its reflected beam is just off the sensitive area of a photodiode connected in one arm of an impedance bridge. As the carbon burns back from the focal point, the image of the crater moves onto the sensitive area of the photodiode, changing its impedance and unbalancing the bridge circuit. The signal from the bridge circuit is amplified by a transistor to operate a relay. The contacts of this relay remove a shunt across the fixed field of a dc motor that normally drives the carbon forward at a rate slightly below its burning rate. Removing the shunt causes the motor to speed up, and this moves the image of the crater off the sensitive area of the photodiode. This sequence repeats rapidly to maintain the crater within a few thousandths of an inch of the focal point of the main reflector.

The arc current is controlled at the same time by a Regohm ten-fingered multicontact relay that adds more or less resistance in shunt with the control field of a 400-cps ac motor that positions the negative carbon.

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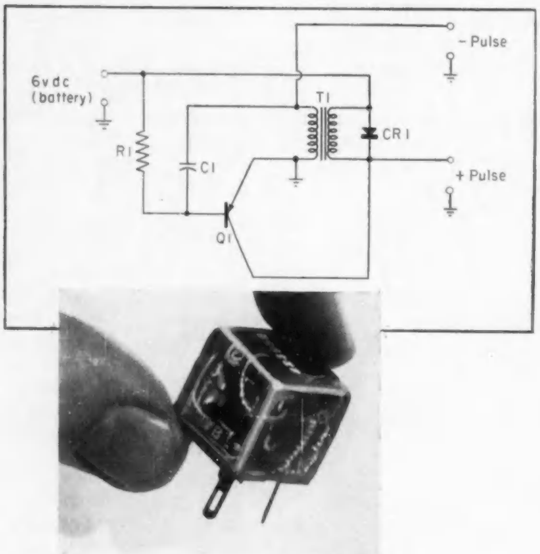


PULSE SOURCE potted in $\frac{3}{4}$-in. cube

Encapsulated within a $\frac{3}{4}$-in. epoxy resin cube, this new blocking oscillator circuit contains all the components shown in the accompanying schematic. These include a subminiature Du Mont pulse transformer, transistor, capacitor, resistor, and crystal diode. The circuit produces triggering electronic pulses that are, in many instances, as useful as those obtained from larger, more expensive pulse generators.

Designated the Du Mont Pulse-Cube, it produces a pulse of 3-microsec duration with a rise time of 0.06 microsec. Amplitude of pulse is from plus 6 volts peak to minus 3 volts peak. Variations of the unit offer fixed repetition rates of 25 kc and 1 kc, or a variable repetition rate from 400 cps to 24 kc. When operating at a 25-kc repetition rate and a 3-microsec pulse width, the unit can run for approximately 1,000 hours.

Available either as a free-running blocking oscillator or as an externally triggered type, the Pulse-Cube can be furnished with plug-in or solder lug terminals. Operating temperature range extends from minus 55 to plus 60 deg C. Because of their miniature size, light weight, and excellent moisture, heat, and shock resistant characteristics, these units should find a number of applications in airborne equipment.—Allen B. Du Mont Laboratories, Inc., Clifton, N. J.

Circle No. 1 on reply card

CONTROL MOTORS for valve operation

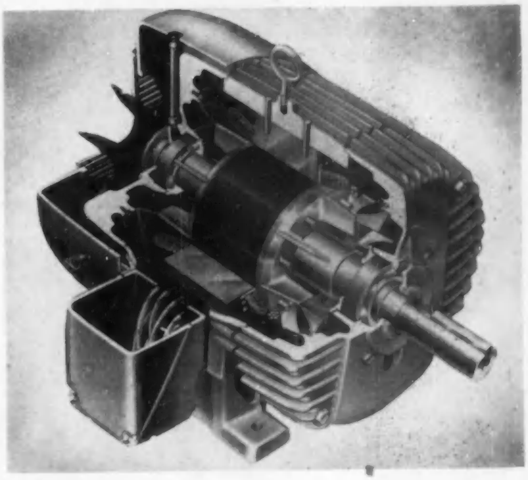
Now in production, this new electric control motor is designed to operate rotary, slipstream, and butterfly valves, dampers, and other final elements.

The motor, a reversing capacitor type known as the Actionator, is being manufactured in two basic models. One unit, the M-630, is designed for two-position and floating control; the second model, the M-930, for proportional control. Both units are compact, measuring approximately 6 in. in diam by 10 in. long. Weight is about 11 lb. They incorporate a gear train that permits a selection of timings from 7.5 to 120 sec, depending on the model. Proportioning control models permit very positive positioning, thereby increasing control accuracy. For example, with a motor of 30-sec timing there are 90 positions of 1.8 deg each.

To prevent coasting in any of the positions, the motors have a built-in internal brake capable of holding a dead-weight load of 200 lb. Field adjustable limit switches vary the travel from 10 to 350 deg on the M-630 and from 10 to 160 deg on the M-930 model. Enclosed compartment will accommodate up to 16 terminals for retransmission, operation of a second motor, or remote position indication. Electrical ratings are 115 or 208 volts, 60 cycles, and 230 volts, 50 or 60 cycles. —Minneapolis Honeywell Regulator Co., Philadelphia, Pa.

Circle No. 2 on reply card

DESIGN CHANGES in 40-125-hp motor line



A new line of ac induction motors ranging from 40 to 125 hp is now in full production. Both open drip-proof and totally-enclosed fan-cooled (photo, right) models are available, in frame sizes 364U through 445U. Built to NEMA standards MGl-3.02.a, MGl-5.05.b, and MGl-5.02.d, the new line features substantial weight and space savings, in addition to higher efficiency, quieter operation, improved performance, and reduced maintenance. Weight reductions average 20 percent, dimension reductions 10 percent, and volume reductions about 27 percent. Other features include: shaved stator wire for maximum smoothness; slot cell insulation with double-backed Mylar polyester; double-end ventilation to eliminate hot spots; and large capacity bearing housings for a new type of synthesized grease. Totally enclosed models also have an external fan of corrosion-resistant, nonsparking Textolite plastic, and a specially designed fan cover.—General Electric Co., Schenectady, N. Y.

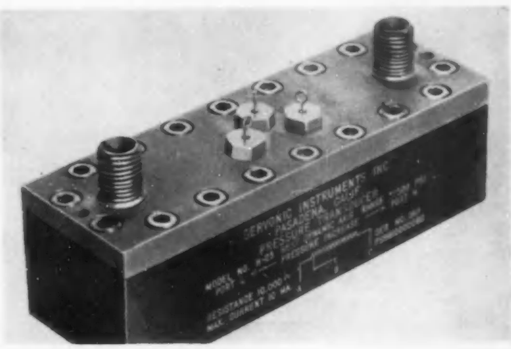
Circle No. 3 on reply card

TACH CALIBRATOR for production testing

Model ST-901 Tachometer Calibrator is basically an electronic decade-type counter combined with the maker's precision electronic adjustable-speed drive. The tachometer under test is driven at a speed (usually between 0 and 5,000 rpm) that is infinitely adjustable by means of a 10-turn potentiometer. For rapid production testing, a pushbutton switch will select any one of five predetermined test speeds. Driving speed is continuously displayed with an accuracy of plus or minus 1 rpm, plus line frequency error. Counter can also be used for checking inverter frequency, telemetering switch counts, etc. Counting speeds to 50,000 per sec are possible. —Servo-Tek Products Co., Hawthorne, N. J.

Circle No. 4 on reply card

PRESSURE TRANSDUCER for rugged duty



Designed primarily for airborne service, this rugged pressure transducer is said to have the ability to operate accurately under vibration environments to plus or minus 20 g's and temperatures to 400 deg F. The instrument incorporates stainless-steel sensing elements which permit the use of corrosive fluids in either gage or differential models. Internal resonances are eliminated, friction effects are minimized, and extremely long potentiometer life is achieved by the use of a special damping fluid. Case and fitting configuration permits compact mounting and easy access to pressure and electrical connectors. Ranges from 1,000 to 10,000 psig or psid are available.—Servonic Instruments, Inc., Pasadena, Calif.

Circle No. 5 on reply card

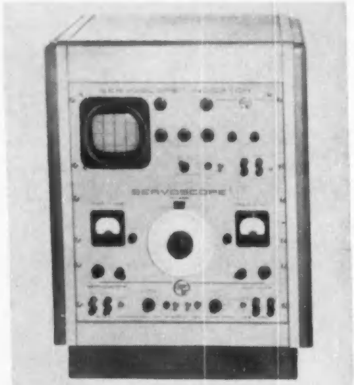
NEW ANALYZER for dynamic strain

The PA-2A Dynamic Strain Analyzer, shown here, provides the highly stable amplification and precise control required for the accurate measurement and oscilloscope display of both static and dynamic strain. Useful sensitivity, attained by combining a high-quality 400-cycle chopper and amplifier, results in a noise level of approximately 3 mv. Frequency response of the amplifier is said to be flat from 5 cps to 50 kc. Any resistive-type strain gage may be used. Ac line operation of the amplifier minimizes maintenance.—Polyphase Instrument Co., Bridgeport, Pa.

Circle No. 6 on reply card

NEW PRODUCTS

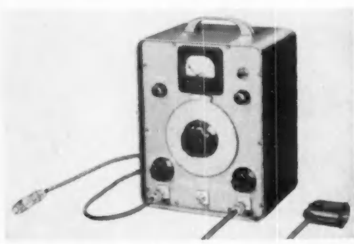
RESEARCH, TEST & DEVELOPMENT



SYSTEM ANALYZER

Model F Servo Analyzer was developed in response to requests for a unit that would accurately measure frequencies as high as 100.0 cps, yet still afford low end coverage at 0.005 cps. This model provides sine, modulated-sine, and square-wave signals as well as the linear sweep on four ranges from 0.005 to 100 cps. Applications include laboratory and production testing of servo systems and components.—Servo Corp. of America, New Hyde Park, N. Y.

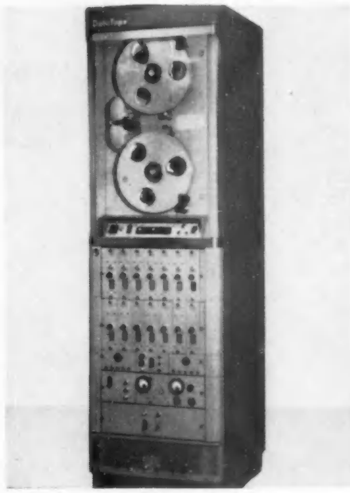
Circle No. 7 on reply card



RATE INDICATOR

The Model PI-114 Transducer System measures directly the rate of change in pressures. Using the "electrostatic" principle, this rugged instrument permits dynamic pressure measurements under the most severe conditions. Ordinarily, pressure applied on the diaphragm end of the pickup compresses a quartz crystal which generates an electrostatic charge proportional to the applied pressure. A calibrator unit then provides an output voltage proportional to this charge. The rate-of-change accessory, attached to the input terminal of the calibrator unit, consists of a BNC Type T adaptor and resistor element. The electrical current (rate of change of charge) generated in the pickup is measured, instead of the magnitude of the charge. Pressure range extends from full vacuum to 3,000 psi with high-pressure adaptors available for service to 30,000 psi. Rise time is 15 microsec. Instrument is especially useful for indicating combustion and detonation phenomena in the evaluation of new engines and fuels. — Kistler Instrument Co., North Tonawanda, N. Y.

Circle No. 8 on reply card



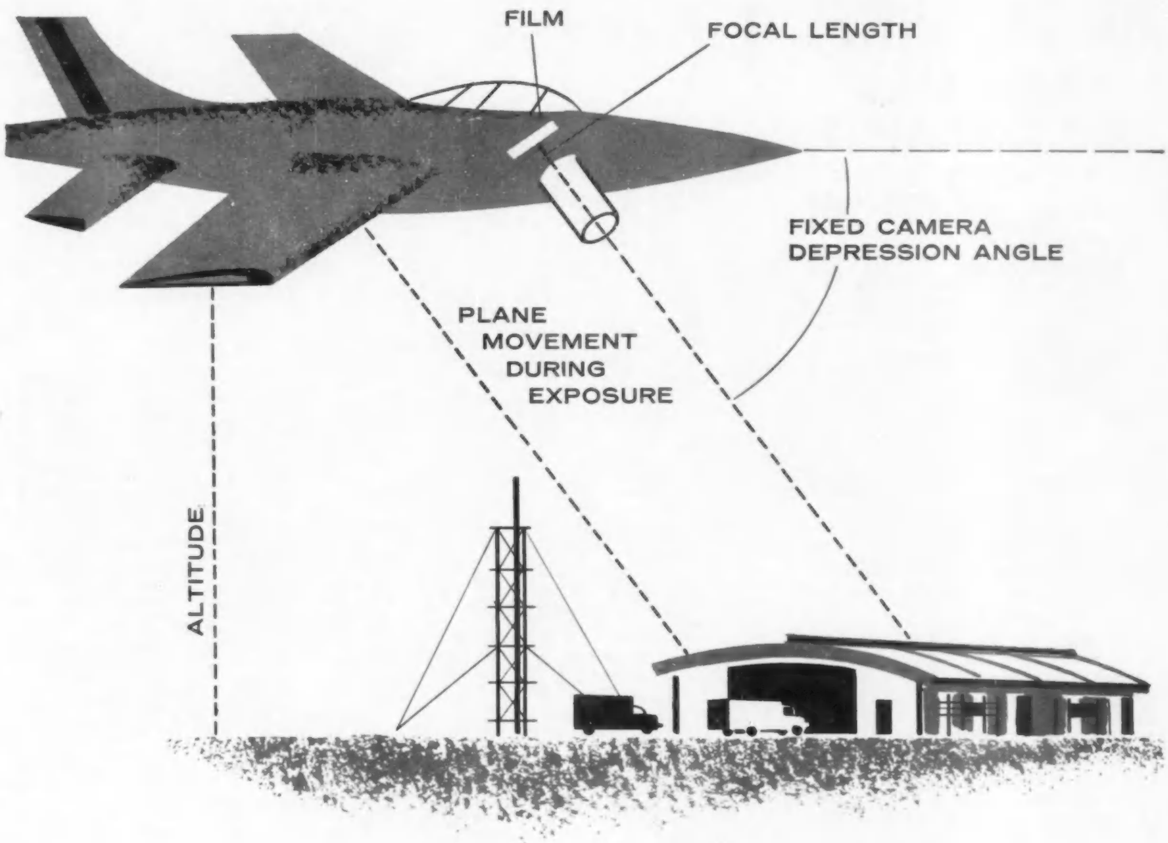
TAPE SYSTEM

Pictured here is the Type 5-752 Magnetic Tape Recorder/Reproducer System, designed to handle analog, PDM, and FM signals. Although specifically developed for telemetering missile data, the system should find wide use in wind-tunnel, engine-test-stand, and other research studies requiring high-speed acquisition of large amounts of precise data. Modular construction permits easy replacement of components and interchange of plug-in amplifiers. Frequency range is from 0 cycles to 100 kc at input levels from 0.25 to 25 volts rms. Dimensions are 2 ft sq and 7 ft high, weight 880 lb, power requirement 115 vac.—Consolidated Electrodynamics Corp., Pasadena, Calif.

Circle No. 9 on reply card

DIGITAL TESTER

The new Union Servo-Ratio Multimeter, an accurate computer-test instrument, measures ac-dc ratios, absolute ac-dc voltages, and resistance. Its 0-deg phase output provides for meas-



How Transicoil servos help aerial camera take clear stills even from low fast planes

It's one thing to take a picture of a moving object. But it's quite another to get good clear shots of the ground from low altitude aircraft moving at today's jet speeds. Universal Camera Control System (UCCS) is the latest development in aerial reconnaissance and photography to solve this problem. Designed and engineered by the Bill Jack Scientific Instrument Co., this novel system actually moves the film through the camera to compensate for image movement during the brief exposure time.

Accuracy of the system is dependent on the airborne DC analog computer having absolute dependability and precision under all the environmental conditions of aircraft flight. Extremes of altitude, temperature and vibration cannot impair its effectiveness.

Transicoil servo assemblies are used extensively in the computer to convert inputs of altitude, ground speed, camera depression angle, and focal length into the correct "film movement" signal.

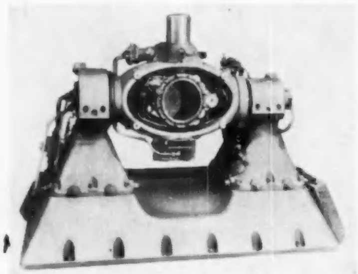
The UCCS application is typical of the way Transicoil rotating components and complete servo assemblies are achieving high orders of accuracy and dependability in countless applications. Transicoil can solve your servo problems with comparable success. A Transicoil Sales Engineer can help you to get off to a good start. A letter from you outlining your servo problem will bring him to your desk.

TRANSICOIL CORPORATION
Worcester • Montgomery County • Pennsylvania

NEW PRODUCTS

urement of gain of operational amplifiers too. It is light, compact, and easily maintained, and includes a four-digit drum counter on the front panel. It will accommodate ac or dc ratios from 0.001 to 1,000, absolute ac or dc voltages from 1 volt to 1,000 volts, and resistances from 10 ohms to 10 megohms, all readings accurate to within 0.1 percent.—Union Switch & Signal Div. of Westinghouse Air Brake Co., Pittsburgh, Pa.

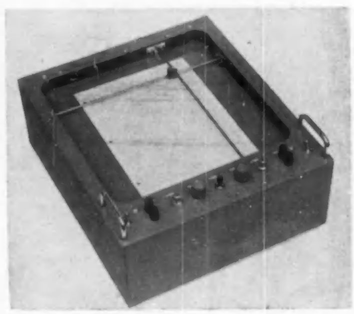
Circle No. 10 on reply card



STUDIES FLIGHT CONTROL

The new Bendix Flight Simulator is said to reduce or eliminate the need for costly trial flights in the evaluation and debugging of airborne systems. Tests on a three-axis flight table and a precise analog simulator control unit can be conducted with angular motions at accelerations and velocities programmed into the computer. The three-gimballed assembly produces roll, pitch, and yaw motions through precision hydraulic servos.—Bendix Computer Div., Los Angeles, Calif.

Circle No. 11 on reply card



X-Y RECORDER

The new $520 Mandrel x-y recorder draws curves in Cartesian coordinates on standard 8½-by-11-in. graph paper. The pen moves along the axes in accordance with voltage signals applied at the input terminals. Unit has a sensitivity of 10 mv per in. and input resistance of 10,000 ohms, and requires 100 watts at 115 volts, 60 cps. Writing speed is 7.5 in. per sec. Applications include computer readout, hysteresis curves, semiconductor and tube characteristics, stress/strain curves, temperature/pressure curves, etc.—Mandrel Industries, Instrument Div., Houston, Tex.

Circle No. 12 on reply card

PORTABLE ANALYZER

Type 21-116 Mass Spectrometer, for laboratory and industry, has an overall mass range of 2 to 80 with resolving power adequate for separation of adjacent peaks up to about mass 35. Features include:

- automatic scanning with manual override
- a record on which mass numbers appear equally spaced on a fixed time base
- a rotary valve that simplifies batch sampling
- separate pumping units and trap elimination
- modular design for optional arrangement

The entire unit weighs only 115 lb. —Consolidated Electrodynamics Corp., Pasadena, Calif.

Circle No. 13 on reply card

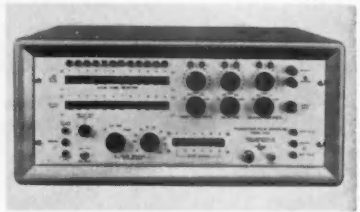
NEW DYNAMOMETERS

To its extensive line of running torque testers and dynamometers, John Chatillon & Sons recently added two new models in the 300 Series and introduced a new 400 Series. Models 311 and 321 torque testers, for applications not requiring high accuracy, retain the lineal dial and wide range. The 400 Series, designed for higher torques, consists of five models ranging in capacity from 4 to 64 ft.-lb. All are

NEW PRODUCTS

equipped with hysteresis brakes and interchangeable springs to reduce capacity. Power dissipations range from 0.8 to 5.25 hp. Maximum speed is either 4,000 rpm or 5,000 rpm, depending on the model.—John Chatillon & Sons, New York, N. Y.

Circle No. 14 on reply card



PULSE GENERATOR
The model 612A Programmed Pulse Generator is said to be able to generate and control a variety of instantly adjustable pulse programs. It generates sine waves or pulses of continuously variable period from 8 to 100,000 microsec. Word length is variable up to 64 digits. The unit also permits setup of an independent pulse train of up to 24 pulses, either positive or negative, direct or time delayed by switch selection. Direct pulse width, delayed pulse width, and delay time may be continuously varied from 1 to 150,000 microsec. — Wang Laboratories, Inc., Cambridge, Mass.

Circle No. 15 on reply card

MEASUREMENT & DATA TRANSMISSION

RESISTS CORROSION
Made entirely from 316 stainless steel, with heliarc welded external joints, this new thermostat is well-suited for service in 5 percent sulfuric acid solutions (at 120 deg F), acetic acid vapors, halide solutions, alkaline solutions, etc. Control temperatures are adjustable from minus 100 to plus 400 deg F, and short-time overshoot by as much as 100 deg will not affect reliability.

Bill Waddell discusses ANALOG/DIGITAL CONVERSION

For the past few years one of the most serious concerns in systems design has been the development of equipment eminently suited to "link" the analog input to the digitized output assemblies of the system. Examples of such links are to be found in radar recording problems in the missile test field, in the control of machine tool operations and, most recently, in data logging in the petrochemical and chemical processing industries. In these and similar instances, there has been a conscious striving to produce highly specialized pieces of conversion equipment in an attempt to adapt the system to the particular control problem at hand.

This striving has also led to increasingly frequent discussions of analog to digital conversion in engineering circles. Such discussions have stimulated interest in, and have actually succeeded in clarifying, basic problems faced by the engineer in producing units suitable for the digitization of specific function variables.

However, contending for attention along with the requirement for restricted-purpose conversion equipment, are the types of analog functions requiring to be digitized. These have continuously increased in numbers, in complexity, and in the imposition of increasingly severe criteria for reliability. To illustrate, systems today are successfully coping with shaft rotations, linear displacements and the complete gamut of electrical signals. A few systems have been built where pressure, temperature, and flow variables have been directly converted.

In the past the tendency has been to design the analog to digital converter and then assemble systems around the converter block. Examples of this approach are to be found in the handling of high-speed serial binary digits from input voltages, and in shaft converters containing cyclic codes requiring complicated translations before the outputs are readily adaptable for further processing. In order to achieve suitable solutions in such cases, it became necessary to introduce auxiliary equipment which frequently turned out to be much less reliable than the digitizer. This led, therefore, to more highly complicated and costly systems rather than significantly simplifying the basic analog to digital converter.

The current approach is to engineer a "link" integrating the components directly into the system. Only in this manner can they be properly weighted to assume their true and economical function. This has resulted in consciously avoiding marrying, for instance, a 5,000 sample per second analog input to a converter capable of spewing out 50,000 samples per second. Or by the same token, feeding 50,000 samples per second into subsequent processing components not adequately provided with control equipment and/or direct methods for recording such rapid outputs.

Bill Waddell, systems input-output specialist, discusses analog to digital conversion.

The present awareness of the problem, however, makes for a most encouraging outlook in the foreseeable future. Design break-throughs are bound to integrate the analog to digital conversion step into its proper and logical relationship to the total system. Systems will then become less complex and significantly more reliable, which undoubtedly will rapidly result in unfolding important new fields suitable for control applications.

By applying the latest proven techniques, our well-qualified staff at Daystrom Systems is prepared to take single responsibility of assembling and installing a system to meet your needs. We are currently compiling a file of new applications and papers on various parts of systems, both industrial and military. If you are interested in receiving the file and periodic additions, please write us.

DAYSTROM SYSTEMS
Division of Daystrom, Inc., 5640 La Jolla Boulevard
La Jolla, California Telephone GLencourt 4-0421

Current rating is 10 amp, 115 vac, or 2 amp, 115 vdc. Only $\frac{5}{8}$ in. in diam, the unit has an immersed length of 3 in. The manufacturer says it will control to within 2 deg F in a well-designed system.—Fenwal, Inc., Ashland, Mass.

Circle No. 16 on reply card

PNEUMATIC AND LINEAR

Shown is the new Type 16A Pneumatic Speed Transmitter, which produces a pneumatic output linearly proportional to rotational speed. It operates on the force balance principle with magnetic actuation of a standard pneumatic circuit. Rotation of the input shaft positions a force bar in relation to an air nozzle. A feedback pressure of 3-15 psig is required to balance the force bar. It is directly proportional to the speed being measured and may be fed to an indicator, recorder, or controller. Speed range is adjustable from 0-1,600 to 0-2,400 rpm and extended to 0-320 through 0-5,300 rpm by optional speed changers. The 3-15-psig output can also be split to accommodate forward and reverse rotation within the maximum range. Unit is particularly suitable for use on turbines, conveyor lines, compressors, and mill equipment. – The Foxboro Co., Foxboro, Mass.

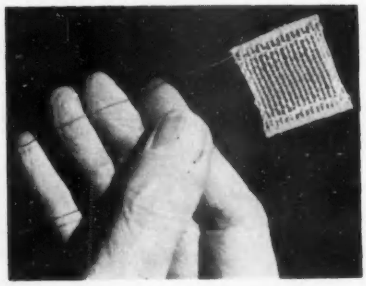
Circle No. 17 on reply card

BAROMETRIC PRESSURE

A new barometric pressure transducer, whose transfer function can be made to match any design requirements, is completely passive and has a very low power consumption. Comparatively unaffected by temperature changes, the unit has a range of from sea level to 40,000 ft, with special units available to 60,000 ft. Input and output im-

pedance levels can be designed to operate with any gyro or signal generator. —Darco Industries, Inc., El Segundo, Calif.

Circle No. 18 on reply card



PLATINUM TRANSDUCER

Designed originally for guided missiles, this new temperature transducer, consisting of a woven grid of fine platinum wire that attaches to any surface with a special dielectric cement, is said to yield much greater accuracy than is ordinarily encountered with resistance temperature measurements. Purchasers can specify a 100-ohm change or more, over an assigned temperature span of 100 to several hundred degrees.—Charles Englehard, Inc., East Newark, N. J.

Circle No. 19 on reply card

INFORMATION DISPLAY INSTRUMENTS

FLOW TOTALIZER

Designed primarily for this company's turbine flowmeters, the new digital totalizer shown here continuously presents the meter output on a seven-digit register. The register consists of a five-digit mechanical counter plus a

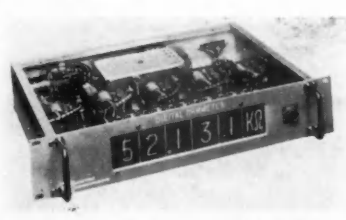
two-digit electronic counter, and shows total pulses, counts, or cycles. Accuracy of the totalizer alone is within plus or minus one count. System accuracy (totalizer combined with the flowmeter) is within plus or minus 0.5 percent of indicated total. Counting rate ranges from 20 to 1,000 cps. Power requirements are nominally 50 watts at 115 vac.—Fischer & Porter Co., Hatboro, Pa.

Circle No. 20 on reply card

MERCURY-ACTUATED

This new mercury-actuated, air-operated, indicating-temperature controller is available in "on-off" and "proportional band" types, and has a wall-mounted cast-aluminum case with bottom outlet, a 5-ft flexible connecting tubing, ¾-in. NPT chrome-plated union fittings, and a stainless-steel bulb for liquid immersion. Standard ranges to 800 deg F are available.—H. O. Trerice Co., Detroit, Mich.

Circle No. 21 on reply card



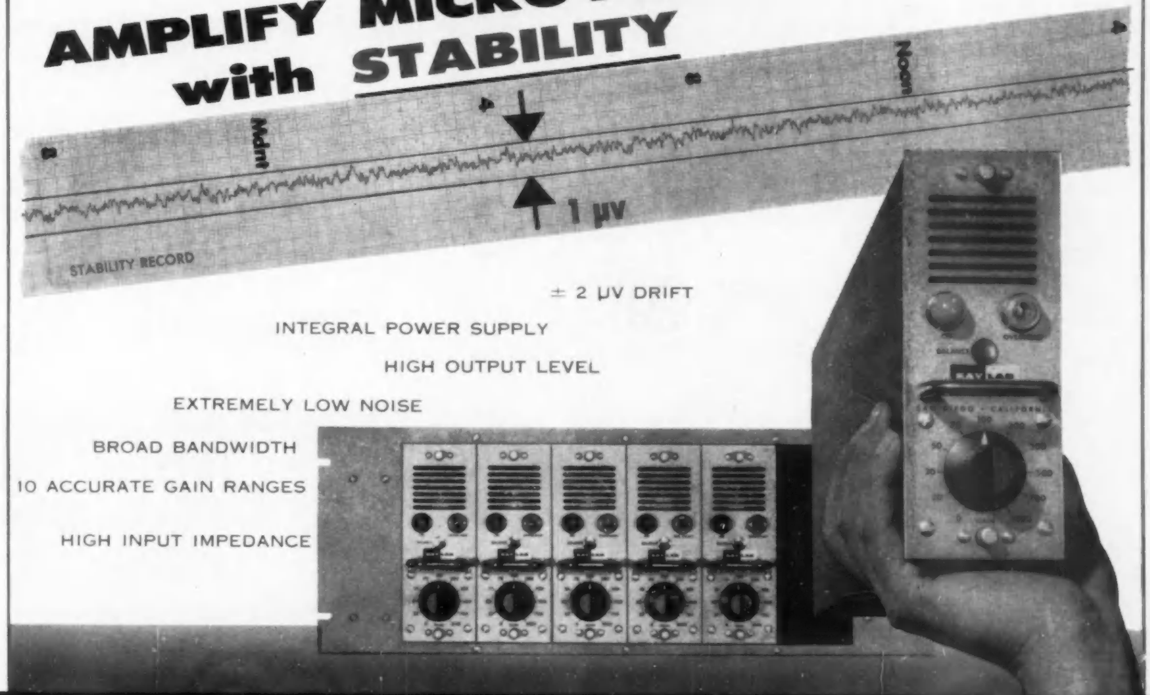
NEW DIGITAL OHMMETERS

Modular construction, transistorized circuits, and a wider dynamic range are features of this new line of digital ohmmeters. Both four- and five-digit models are available. Resistance measurements from 10 milliohms to 10 megohms can be made in the same instrument. Ranging is automatic, but

KIN TEL [KAY LAB]

FOR DRIFT-FREE DC INSTRUMENTATION

AMPLIFY MICROVOLTS with STABILITY



± 2 µV DRIFT

INTEGRAL POWER SUPPLY

HIGH OUTPUT LEVEL

EXTREMELY LOW NOISE

BROAD BANDWIDTH

10 ACCURATE GAIN RANGES

HIGH INPUT IMPEDANCE

The **KIN TEL** Model 111 amplifier provides maximum stability and the lowest drift of any commercially available broadband d-c amplifier. It is the end result of years of research in the field of chopper stabilized broadband d-c amplifiers. Thousands of **KIN TEL** amplifiers are in daily use. The Model 111 incorporates **KIN TEL's** proven chopper amplifier circuitry and provides ten extremely precise, feedback controlled gain ranges. Several feedback loops assure high accuracy, stability and uniform frequency response. The completely new and unique circuit provides rapid recovery from severe overloading and unsurpassed dynamic performance—unaffected by load or gain changes.

The Model 111 is available in a single-unit cabinet or in a six-unit rack-mountable module. The amplifiers are extremely compact; the six-unit module occupies only a 19-inch rack width.

APPLICATIONS: The Model 111 is ideal for permanent low level d-c instrumentation, telemetering, or as a strain gage amplifier, transducer amplifier, scope preamplifier, recorder driver amplifier, or general purpose laboratory amplifier.

SPECIFICATIONS

Gain	0, 20, 30, 50, 70, 100, 200, 300, 500, 700, 1000
Gain Accuracy	± 1% DC to 2 KC
Input Impedance	100,000 Ω
Output Capability at DC	0 to ± 35 V where $R_L > 1000\ \Omega$ 0 to ± 40 MA where R_L is 10 to 400 Ω
Output Impedance	Less than 1 Ω in series with 25 µh
Equivalent Input Drift	± 2 µv with regulated line
Equivalent Input Noise	0 to 3 cps, less than 5 µv peak to peak 0 to 750 cps, less than 5 µv RMS 0 to 50 kc, less than 12 µv RMS
Chopper Intermodulation	Less than 0.1%
Linearity	Better than 0.1% to 2 KC
Frequency Response	± 3% (0.3 db) DC to 10 KC, less than 3 db down at 40 KC

Power Requirements:	
Amplifier	117 V – 60 cycles – 70 VA
Cabinet	117 V – 60 cycles – 15 VA
6 Unit Rack Adaptor	117 V – 60 cycles – 45 VA
Dimensions: Amplifier Unit	2⅞" wide, 7⅝" high, 14⅝" deep
Rack Adaptor for 6 Units	19" wide, 8¾" high, 18¼" deep
Net Weight – Amplifier	11 pounds
PRICE: Amplifier Unit	$550.00
19-inch Rack Adaptor for 6 amplifier (with fans and connectors)	200.00
Cabinet for single amplifier (with fan and connector) is available.	

...the Standard in chopper-stabilized instruments

KIN TEL [KAY LAB]

STABILITY *locked in!*

WITH CHOPPER AMPLIFIERS

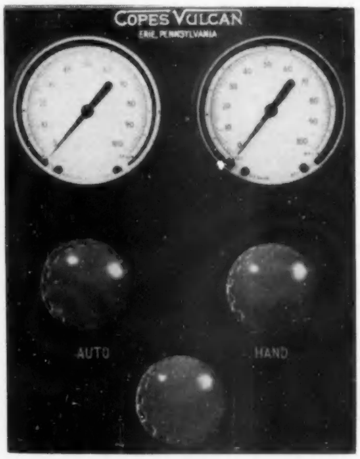
Representatives in all major cities.

5725 KEARNY VILLA ROAD, SAN DIEGO 11, CALIFORNIA · BROWNING 7-6700.

can be programmed by means of controlling contacts in the rear panel. Accuracy varies from 0.01 percent plus or minus two digits to 0.1 percent plus or minus one digit, depending on the range used. The five-digit model features a 1.5-sec readout time. Electro Instruments, Inc., San Diego, Calif.

Circle No. 22 on reply card

CONTROL DEVICES



"BUMPLESS" TRANSFER

A new line of auto-manual pneumatic-control loading stations is said to assure "bumpless" transfer from automatic to manual positions or vice versa without process disturbance or upset. This design omits one control station in many cascade control circuits. Pressure range is 3 to 15 psig with gages scaled from 0 to 100 percent. Both standard and miniature models are available. Units are suitable for use as components in combustion, feedwater regulation, pressure reduction, and desuperheating control systems.—Copes Vulcan Div. of Blaw-Knox Co., Erie, Pa.

Circle No. 23 on reply card

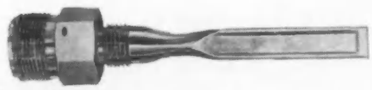
SAMPLING SWITCH

A miniaturized version of this company's Type A Sampling Switch weighs only 7 oz and is 2 1/4 in. on its largest side. A two-pole unit with 30 contacts per pole, it will provide 60

TEMPERATURE

EDISON'S resistance temperature detectors

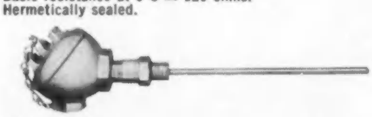
eliminate signal amplification



MODEL 235N90-35
Designed for fast response and high resistance to the corrosive effects of rocket fuels used in guided missiles.
SPECIFICATIONS:
Stem-sensitive.
Useable temperature range —70° to +200°C.
Exponential time constant in agitated waterbath 0.8 second. Maximum hydrostatic pressure on stem: 750 psi at 100°C.
Basic resistance at 0°C = 90 ohms.
Hermetically sealed.

MODEL 242P
This Detector can be operated in live steam or high temperature atmospheres up to 1300°F.
SPECIFICATIONS:
Stem-sensitive.
Useable temperature range —70° to +750°C.
Maximum hydrostatic pressure on stem: 300 psi at 750°C.
Basic resistance at 0°C = 100 ohms.
Hermetically sealed.

MODEL 230N
A general purpose Detector for temperature measurement and control in industrial processes.
SPECIFICATIONS:
Stem-sensitive.
Basic resistance at 0°C = 120 ohms.
Hermetically sealed.



MODEL 166NC
Element is concentrated in tip for sensitivity to sur face temperatures in motor bearings, etc.
SPECIFICATIONS:
Tip-sensitive.
Useable temperature range —70° to +300°C.
Basic resistance at 0°C = 120 ohms.

FROM THE MONITORING OF VOLATILE HYDROGEN PEROXIDE . . . TO THE CONTROL OF CRITICAL MOTOR SLEEVE BEARING TEMPERATURES

Edison, leader in the research and development of temperature control systems, applies the principle of the simplified bridge circuit. Resistance Temperature Detectors form one arm of this bridge to eliminate the need for signal amplification. These Detectors are hermetically-sealed in a corrosion-resistant steel well and terminate in leads of ordinary copper wiring. Hermetically sealed detectors in normal service can be expected to show less than 0.05% resistance calibration over a five year period.

Resistance tolerance of ±0.5% for stem-sensitive detectors and ±1.0% for tip-sensitive detectors are inherent in production.

Edison's exceptional production facilities and technique of hermetically sealing the element give these detectors exceptionally long life and stability. For this reason they are specified for use in corrosive atmospheres of the type found in exotic fuels used to propel guided missiles, chemical processes and in nuclear reactors.

Because of its high accuracy and exceptional stability, the Resistance Temperature Detector is used as a measurement standard for part of the international temperature scale. Response time as high as 0.25 seconds has been achieved.

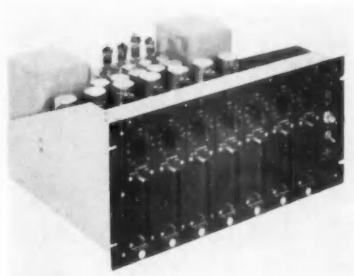
Edison's Detectors may have applications in your individual control system. Call, or write today for Brochure No. 3016D for additional details.

Thomas A. Edison
INDUSTRIES
INSTRUMENT DIVISION — WEST ORANGE, NEW JERSEY

McGRAW EDISON

channels in make-before-break operation. A filtered 27.5-volt dc motor rotates the switch at 2.5 rps for a rate of 150 samples per sec. Makers claim this rugged little switch will give up to 300 hours of service-free operation. —Applied Science Corp. of Princeton, Princeton, N. J.

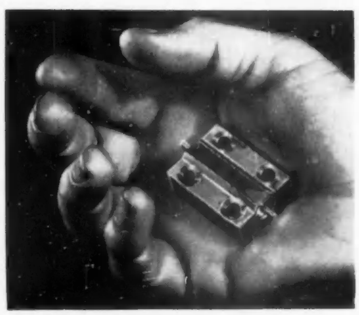
Circle No. 24 on reply card



AMPLIFIER SYSTEM

The seven-channel ac voltage amplifier system above is said to be exceptionally linear in phase and amplitude characteristics from 2 to 100,000 cps. At present it is being used in recording transducer signals on standard wide-band magnetic tape equipment used in rocket-motor development. Each channel may be set to any one of 11 steps of voltage gain from 1.0 to 100. The changes, entirely in the feedback networks, do not affect the signal-to-noise ratio. The self-contained unit requires only a 117-volt, 60-cps source.—Dynamics Instrumentation Co., Div. of Alberhill Corp.

Circle No. 25 on reply card



HYDRAULIC AMPLIFIER

This new 4-oz hydraulic amplifier operates without an amplified input signal. Instead, it takes direct signals from gyros, accelerometers, diaphragms, and torque motors (driven directly from potentiometers) to con-

trol flow or pressure output as a function of input displacement or force. It produces a wide range of proportional outputs in terms of flow, position, and force, either simultaneous with, or independent of, the initial signal.—Manning Aircraft Products Div. of Manning, Maxwell & Moore, Inc., Inglewood, Calif.

Circle No. 26 on reply card

INDICATES AND CONTROLS

The new Synchro-Scan Position Indicator/Controller, consisting of a transmitting unit (above) and a receiving unit (not shown), permits remote modulation and continuous indication of valve position and other variables. A three-position switch on the transmitter opens, closes, and stops the valve. Above the switch is a small, voltmeter-type indicator graduated from 0 to 100 percent to indicate actual position of the valve. The receiver unit contains the control relays and a regulated dc voltage supply for transmitting position indication. —Builders-Providence, Inc., Providence, R. I.

Circle No. 27 on reply card

MILL REGULATOR

A new dual-circuit, variable-speed electronic mill regulator (designated VSMR) is now available for high-performance, continuous-process mills for paper, rubber, glass, and nonferrous metals industries. Basically, the new unit operates on two parallel sets of thyratron tubes. Normally, the tubes tend to share the load. However, in case tubes fail in one half of the regulator, the tubes in the operable half immediately take over the full load.

MAGNETIC
TAPE
APPLICATIONS
BY AMPEX

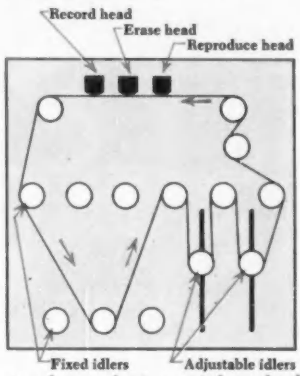
ONE OF A SERIES 4

How to use the recorder that chases its tail

The continuous loop solves a variety of tricky problems

At first glance the tape-loop recorder is rather like a puppydog chasing its tail. But don't be fooled — electronically, it is as interesting as a re-invention of the wheel. And you can share the challenge of its practical uses.

Are you waiting for lightning to strike? Let a tape-loop recorder stand the watch. It has infinite patience and a perfect sense of anticipation. The tape loop continuously records and erases until an important event takes place. At that moment everything is on the loop — even the important instants before. The tape loop either stops at the end of a cycle or it starts up a reel-to-reel recorder to copy the data. This scheme is used to study natural phenomena, to handle intermittent communications, and to collect data on abrupt mechanical or electrical failures.



The tape loop cycles in a period equal to loop length divided by tape speed. Movable idlers plus use of varying numbers of fixed idlers accommodate any loop length from minimum to maximum. Data can be repeated indefinitely or can be continuously erased.

For time-delay applications, the tape loop is like a conveyor belt for information. The tape continually receives data at the record head. Data rides the tape around the loop to the reproduce head and is withdrawn at a predetermined time delay. The interval is determined by length of tape loop and tape speed. Uses are machine and process control, communications memory, and handling of computer data.

The tape-loop recorder also has a talent for repetition. A short loop synchronized with the sweep rate of an oscilloscope provides a repeating signal that makes transient data stand still. For wave analysis, the tape loop reproduces a sample of data repeatedly until it has been scanned for all significant frequencies by a succession of filters. Even a short transient can be analyzed.

The new Ampex FL-100 Tape-Loop Recorder being used with an Ampex FR-100 Reel-to-Reel Recorder. Interchangeable plug-in units make the two compatible with any combination of track characteristics.

For processing or simulation devices, the tape loop provides a program-control cycle of great sensitivity. Tape-controlled repetitions are as identical in pattern as the successive cycles of a mechanical cam — but have advantages of electrical control and infinite variations possible with tape.

Newest of Ampex's tape-loop recorders is the FL-100. It shares the styling and features of Ampex's FR-100 and FR-1100 recorders. The FL-100 uses their same interchangeable plug-in amplifiers, hence each track can be used with any of three recording characteristics. Frequencies from DC to 100,000 cycles can be recorded.

Loop length on the Ampex FL-100 is continually variable from a minimum of 3½ feet up to one of three optional maximums — 25, 50 or 75 feet. Tape widths are quarter, half and one inch. Up to eight tape speeds are available on the same machine. Overall speed ratios can be as high as 128 to 1.

If you would like further information on Ampex's new FL-100 Tape-Loop Recorder — or if you have a special problem to which it is applicable, Ampex's application engineers will be pleased to provide added details. Also, would you like to have this informative ad series mailed to you direct? Write Dept. HH-4.

Series FR-100

Series 800 Mobile and Airborne

Model FR-200 Digital

Series FL-100 Loop Recorders

Series FR-1100

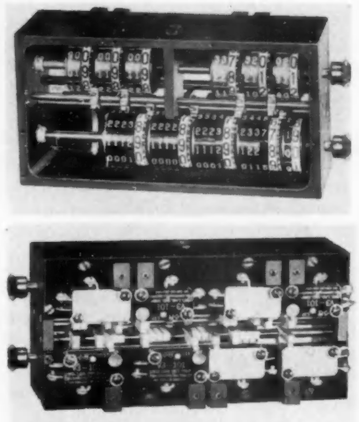
INSTRUMENTATION DIVISION
AMPEX CORPORATION
FIRST IN MAGNETIC TAPE INSTRUMENTATION
934 CHARTER STREET • REDWOOD CITY, CALIFORNIA

District offices serving all areas of the United States and Canada; Foreign Representatives in countries around the world.

NEW PRODUCTS

The use of thyratrons in the output section does away with circuit tuning and matching. The output section will operate into the motor field or generator field of any drive to accurately control speed, tension, and voltage within the rated limit of a single pair of tubes.—Reliance Electric & Engineering Co., Cleveland, Ohio.

Circle No. 28 on reply card



PROGRAMMER COUNTER

Developed for missile guidance systems and starting sequence systems, this new Programmer Counter will close from one to eight or more switches at selective predetermined settings within a given range. Settings are made by rotating cam rings to the numbers desired. The double-deck, end-driven counter will operate at input shaft speeds of up to 500 rpm. Durant Manufacturing Co., Milwaukee, Wisc.

Circle No. 29 on reply card

TEMPERATURE CONTROL

Shown is one model of the new Series 2300 thermocouple temperature con-

trols, whose V.H.S. Meter Relay, load relay, and other components are contained in a compact steel case. Control action may be either limit or automatic: limit units trip a relay and lock and must be reset externally; they can be used for temperature monitoring or alarm; automatic models include an automatic interrupter for periodic reset and are suitable for control of heaters and coolers. Temperature ranges are minus 400 to plus 3,000 and minus 240 to plus 1,650 deg C. Units accommodate all standard type thermocouples and have accuracies of 95 or 98 percent depending on the ambient temperature range involved. Power requirements are 115/230 vac, 50/60 cps; dc and 400 cps models are optional.—Assembly Products, Inc., Palm Springs, Calif.

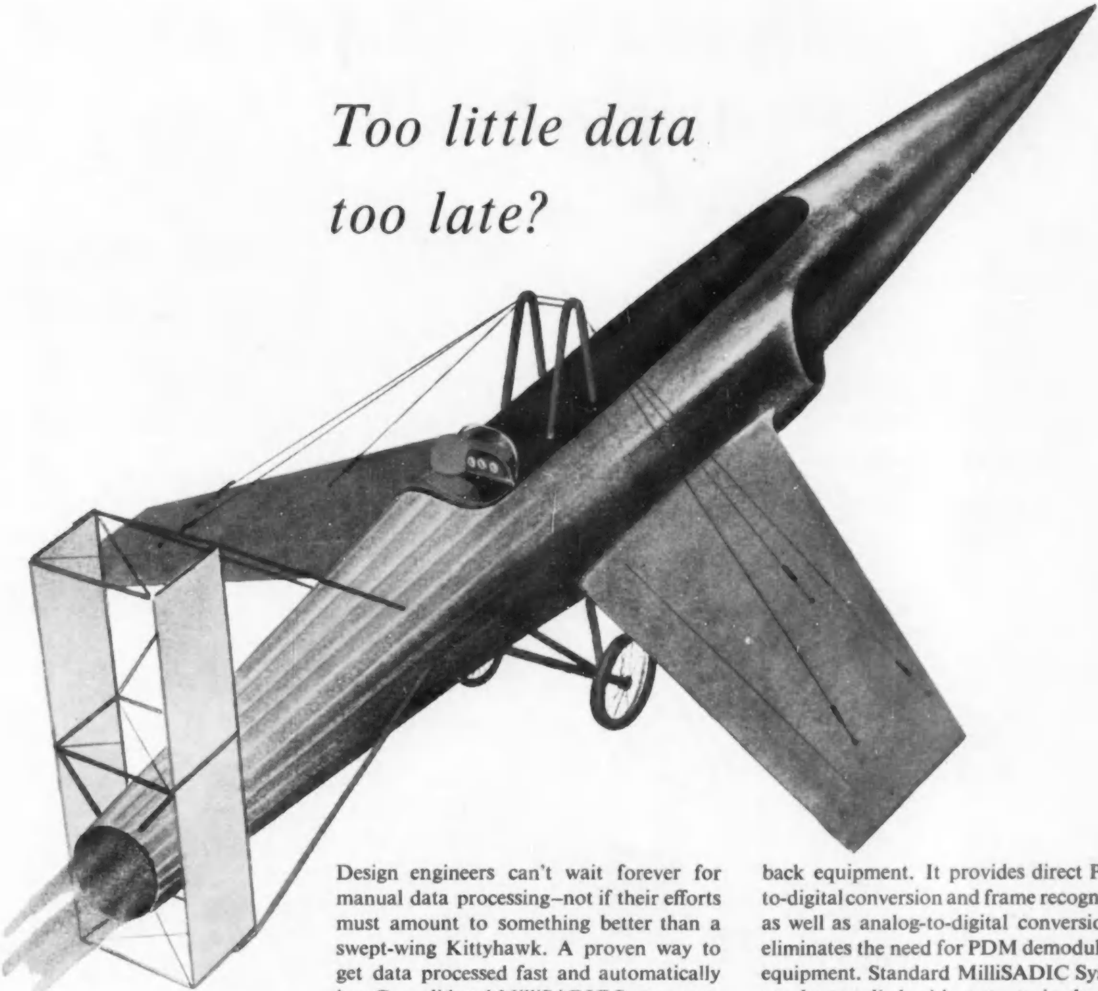
Circle No. 30 on reply card

24-HR TIME SWITCH

All types of intermittently operated equipment can be handled by this new 24-hr time switch. Typical applications include oil wells, heating and air-conditioning equipment, stokers, and oil and gas burners. A control dial scaled in 15-min graduations sets up a daily operating schedule. Sliding self-contained, nonremovable trip levers in or out on the dial establishes running periods. The device, powered by a heavy duty synchronous industrial motor, uses 60 cycle current and has a capacity of 1,000 watts.—Zenith Electric Co., Chicago, Ill.

Circle No. 31 on reply card

Too little data too late?



Design engineers can't wait forever for manual data processing–not if their efforts must amount to something better than a swept-wing Kittyhawk. A proven way to get data processed fast and automatically is a Consolidated MilliSADIC System, custom-tailored to your specific requirements.

MilliSADIC accepts commutated input from either telemetry receivers or tape playback equipment. It provides direct PDM-to-digital conversion and frame recognition, as well as analog-to-digital conversion. It eliminates the need for PDM demodulation equipment. Standard MilliSADIC Systems can be supplied with outputs in the form of punched cards, or digital recordings on magnetic tape. For full information contact your nearby CEC field office, or write for Bulletin CEC 3003-X14.

CEC's
MILLISADIC
data-processing systems

Versatile MilliSADIC Systems rapidly pay for themselves by speeding reliable data reduction. Programming and operation are extremely simple. Operational modes are flexible –single channel, single sample, commutated, commutated sweep and external signal.

Consolidated Electrodynamics

300 North Sierra Madre Villa, Pasadena, California

OFFICES IN PRINCIPAL CITIES THROUGHOUT THE WORLD

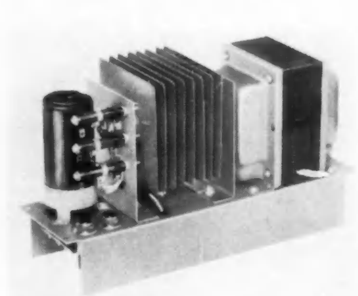
NEW PRODUCTS

POWER SUPPLIES

SOLID-STATE POWER

This new transistorized, regulated dc to dc power supply weighs 19 oz and measures 3 in. in diam by 3 in. high. It operates from an input of 24-30 vdc. Outputs are available from 25 to 1,200 vdc, with power up to 60 watts continuous duty. Unit is regulated against both line and load variations. In a 50-watt unit, line variations of 22 percent are reduced to 1 percent in the output. Load variations from 10 percent to full load are similarly attenuated. Units are designed to meet MIL-E-5272A, including Procedure I for vibration.—Arnold Magnetics Corp., Los Angeles, Calif.

Circle No. 32 on reply card

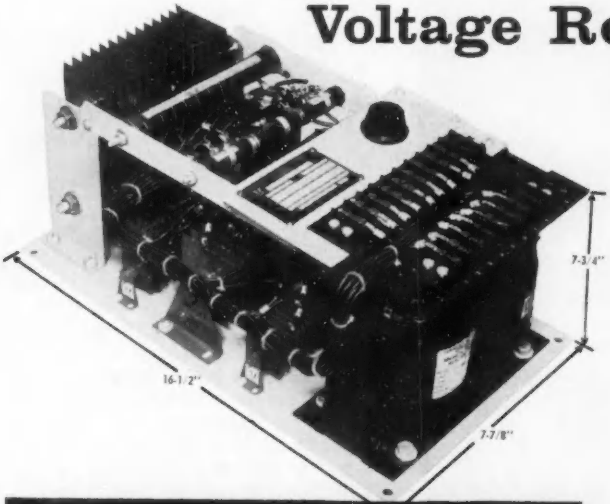


28-VDC SUPPLY

This 28-vdc, 5-amp power supply for operating relays, motors, filaments, and control equipment uses magnetic-amplifier circuitry for dependability and long life. Regulation is within plus or minus 0.25 vdc from no load to full load, or with line voltage changes of from 105 to 125 vac.—Dressen-Barnes Corp., Pasadena, Calif.

Circle No. 33 on reply card

Now! A Low-Priced Completely Static Voltage Regulator

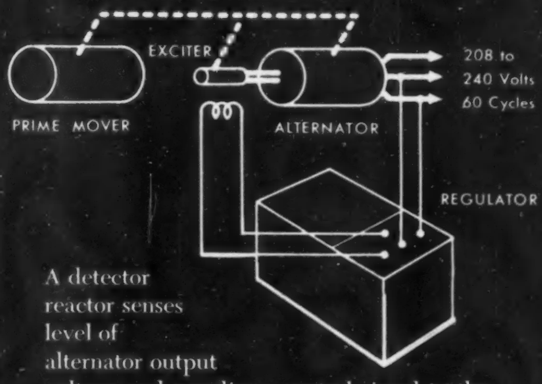


by

VICKERS*

For Fast, Accurate Voltage Regulation of 60-Cycle Alternators

How the Vickers Static Voltage Regulator Works



A detector reactor senses level of alternator output voltage and supplies a control signal to the magnetic amplifier stage. The amplifier in turn maintains alternator output voltage constant by supplying controlled excitation to the exciter. A regulator control knob permits adjustment of alternator voltage.

This new unit is ideal for applications where a simple and inexpensive but rugged voltage regulator is desired. The Vickers regulator is a single-stage magnetic amplifier unit utilizing selenium rectifiers and wire wound resistors. It is completely static, with no moving parts, and is thus not affected by vibration. Other features:

- Works into 20 to 100 ohm exciter field resistance without adjustment.
- Supplies exciter field current within a range of 0.15 to 1.35 amperes.
- Connects directly to 208 to 240 alternator without need of a potential transformer. Operates with alternators having any output voltage when used with a 500 VA potential transformer.
- Adjustable line drop or reactive current compensation provides zero droop at a given load when a Vickers accessory current transformer is used.
- Extremely simple to install, with only 6 terminal connections.

* Trade Mark

Write Today for Complete Information, Including New Brochure, on the Vickers Static Voltage Regulator.

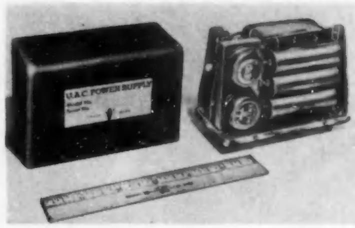
VICKERS ELECTRIC DIVISION

VICKERS ELECTRIC DIVISION
VICKERS INCORPORATED a unit of Sperry Rand Corporation

1805 Locust St. Saint Louis 3, Missouri

LEADERS IN ELECTRICAL CONTROL EQUIPMENT
Magnetic Amplifier Components and Control Systems
Selenium Rectifiers • Magnetic Particle Brakes and Clutches
Photoelectric Cells

NEW PRODUCTS

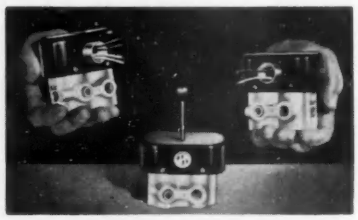


LIGHTWEIGHT POWER

A new series of tubeless, transistorized dc-to-dc power converters for portable or airborne electronic equipment is a rugged improvement over heavier, less-efficient power supplies. Standard units are available for 12- and 28-volt inputs in a number of nominal output voltages from 120 to 2,100 volts, and in power outputs up to 500 watts. Regulation is available to 0.25 percent. Standard operating temperature range is from minus 40 to plus 71 deg C. Units can be made to meet MIL specs, and can be as compact as ½ cu in. per watt and as light as $\frac{1}{10}$ oz per watt.—UAC Electronics, Div. of Universal Transistor Products Corp., New York.

Circle No. 34 on reply card

FINAL CONTROL ELEMENTS



NEW FOUR-WAY VALVES

Recent additions to this company's line of "Quick Dump" control valves are these three new four-way, five-port models, two electrically operated and the third equipped with a hand lever. One electric model is a momentary impulse type in which a single electric impulse opens one valve section and closes the other. No current is needed to hold the valve in position. The other electric valve, a "fail-safe" type, holds a given position until current is shut off or an electrical failure occurs. An electromagnetic armature (not

NEW PRODUCTS

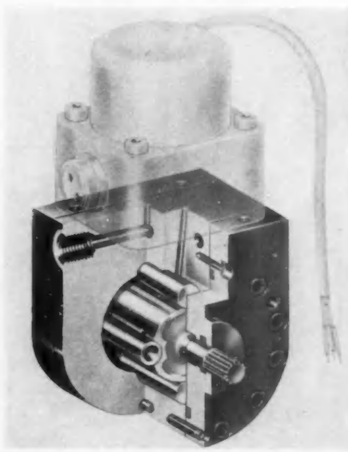
solenoid) travels only 0.022 in. in actuating the valve. Full ¼-in. internal ports provide 80 cfm of air at 100 psi, ample capacity for operating double-acting cylinders up to 4½ in. in diam. —Humphrey Products, Div. of General Gas Light Co., Kalamazoo, Mich.

Circle No. 35 on reply card

LOW-COST MIDGET

Only 3⅛ in. high and 1⅞ in. in diam, model K-27-H solenoid valve is suitable for all common industrial fluids, including water, oil, gas, and air, at operating pressures up to 130 psi. The normally closed valve is available in ⅛ in. IPS, and features a spring-loaded plunger with soft seat for bubble-tight shutoff, a brass-bar-stock body, and a two-wire continuous duty solenoid. Valve is designed especially for the low-price field.—General Controls Co., Glendale, Calif.

Circle No. 36 on reply card



HYDRAULIC ACTUATOR

Suitable for positional control servo systems in the 3,000-to-4,500-psi range, this new rotary hydraulic actuator features a static breakaway friction of less than 1 percent of maximum stall torque, low internal leakage, and minimum load-coupling compliance. Sizes range from 100 to 600 lb-in. stall torque (rated at 3,000-psi supply pressure). Most units provide for integral-mounting of standard valves, with pressure and return ports per AND-10050. —Aviation Div. of Kelsey-Hayes Co., Detroit, Mich.

Circle No. 37 on reply card

NEW
ELECTRONIC GALVANOMETER

dc null detector

micro-microammeter

microvolt level dc amplifier

microvoltmeter

Sensitive - Rugged - Versatile

Functionally equivalent to suspension galvanometers, but with far greater versatility, the Model 204A is the ultimate for DC null detection in low level bridge and potentiometer circuits. KIN TEL's chopper stabilized, all transistor design provides extreme sensitivity and rugged durability superior to conventional moving coil or electronic galvanometers.

Immune to overload and shock, the current sensitivity of the Model 204A is 20 times greater than the sensitivity of high quality, mechanical current galvanometers. As a voltage galvanometer, the extremely high power sensitivity of the Model 204A makes it superior to low impedance moving coil instruments. This reliable, general purpose unit is ideal for use as a direct reading indicator for strain gage thermocouple and other current or voltage measurements in industry or laboratory. The 204A's simplicity of operation makes it the key to efficient production line testing. Its unequalled stability makes it ideal for low level DC amplification to extend the range of recording and other measurement instruments.

Representatives in all major cities.

A dozen good reasons why KIN TEL's Electro-Galvo solves your low-level dc measurement problems

1 20 Micro Microamps Per Division Sensitivity

2 ± 10 Microvolts to 10 Volts or ± 0.001 Microamp to 1 Milliamp Full Scale Sensitivity

3 Withstands Extreme Overload with No Zero Offset

4 Transistorized — Rugged — Insensitive to Shock, Microphonics, Position

5 Floating Input

6 7 Voltage or Current Ranges

7 10,000 Ohm Input Resistance

8 10^{-14} Watts Full Scale Power Sensitivity

9 Equivalent Built-in Ayrton Shunt — No Accessories to Buy

10 Use as Stable DC Amplifier with 1 Volt at 1 ma Output

11 Less than 2 Microvolts Drift

12 Less than 1 Microvolt P-P Noise

Model 204A Price $325.00

KIN TEL (KAY LAB)

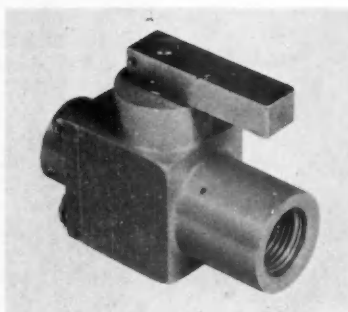
5725 KEARNY VILLA ROAD • SAN DIEGO 11
CALIFORNIA • BROWNING 7-6700

NEW PRODUCTS

ALL-METAL ACTUATORS

Available with or without control valves, these new all-metal (bellows) actuators function either "air to open" or "air to close", and are readily reversed in the field. Signal pressure ranges are 3 to 15, 6 to 30, and 9 to 45 psi, and maximum thrust is about 3,000 lb. Measurements are 17 9/16 in. long by 8 5/8 in. in diam. One unit, available "air to close" only, is fabricated completely of stainless steel.—Fulton Sylphon Div. of Robertshaw-Fulton Controls Co., Knoxville, Tenn.

Circle No. 38 on reply card



BALL VALVES FOR 3,000 PSI

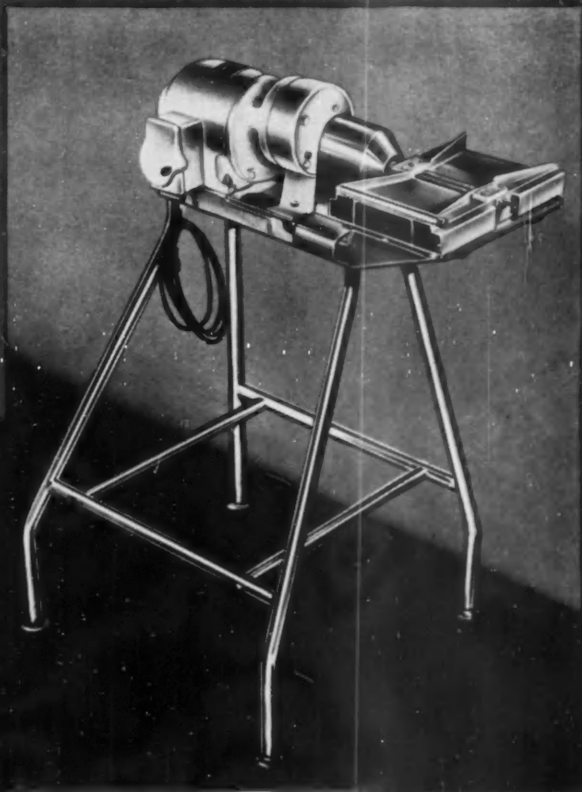
Shown is one of a new line of manually operated ball valves for bubble-tight flow control of many fluids at pressures up to 3,000 psi. Design incorporates a self-wiping and self-lapping action that is said to assure long, trouble-free life. Other features in-

THERE'S MORE

THAN **ONE** WAY

TO SKIN A

GIZZARD!



Power Gizzard Skinner Means Better Production for packers! Driven by a Master ¼ H.P. Double Parallel Gearmotor, output speed 230 R.P.M.

ANOTHER DRIVE REQUIREMENT MEETS ITS MASTER

"But my drive problems are different," you say, and right you undoubtedly are. Far as we know, this Master-powered Gizzard Skinner is unique.

But here's the point. America's productive genius consists of the ability to analyze a problem, devise a system and apply power to it in such a way as to produce better results faster at less cost. And *that problem* we bet you've got!

Let us help! Tell us the problem. From the drives listed here—or a combination of the required ones in one compact efficient unit—we'll deliver the goods! That's just what we've done for many, many years, to an ever-enlarging cross-section of American industry jealous of the performance of their motor equipment.

Motor Ratings..⅛ to 400 H.P. All phases, voltages and frequencies.

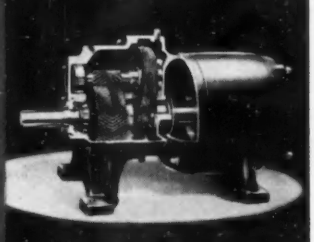
Motor Types.....Squirrel cage, slip ring, synchronous, repulsion-start induction, capacitor, direct current.

Construction.....Open, enclosed, splash-proof, fan-cooled, explosion-proof, special purpose.

Speeds................Single-speed, multi-speed, and variable speed.

Installation........Horizontal and vertical, with or without flanges and other features.

Power Drive Features............Electric brakes (2 types)—5 types of gear reduction up to 432 to 1 ratio. Mechanical and electronic variable speed units—fluid drives—every type of mounting.

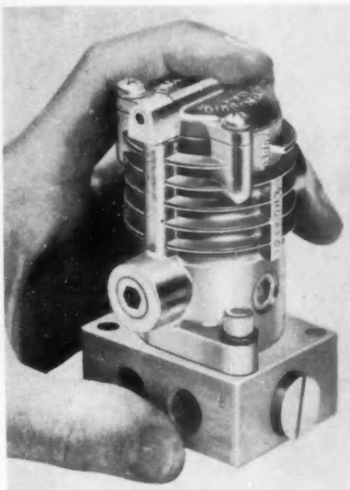


THE MASTER ELECTRIC COMPANY

Dayton 1, Ohio

clude: zero leakage at all pressures to 3,000 psi; straight-through design to assure zero relative pressure drop at all flow rates, and operating temperatures of from minus 320 to plus 650 deg F. Valves are suitable for hydraulic fluids, fuels, oxydizers, water, oils, air, etc. Available sizes range from ¼ to 4 in. Typical ⅜-in. model weighs only 0.3 lb.—Hydromatics, Inc., Cedar Grove, N. J.

Circle No. 39 on reply card



SOLENOID-PILOTED

This miniaturized, pilot-operated, four-way valve is said to be well suited for the control of small double-acting cylinders and similar devices. The unit is only 4 in. long and weighs 30 oz. Its four-way action is achieved with a single solenoid pilot and a pressure-balanced shuttle in the valve body. Solenoid pilot is built to JIC standards, and manufacturer guarantees coils against burnout for life of the valve. Units are designed for two-point mounting, and may be used with pressures of from 15 to 140 psi. All ports are tapped ¼ in. NPT.—Valvair Corp., Akron, Ohio.

Circle No. 40 on reply card

MAGNETIC CLUTCH

A new line of magnetic clutches for machine tool control and other industrial applications features comparatively short axial and small radial dimensions, complete isolation of the magnetic assembly from the integral mechanical parts, and compact assem-

bly of all components. Stationary field or brush types are available for either "wet" or "dry" operation. Maker claims reduction of decay time and residual drag to an absolute minimum. —Fawick Airflex Div. of Fawick Corp., Cleveland, Ohio.

Circle No. 41 on reply card

COMPONENT PARTS

QUALITY CORES

A new magnetic core, called Hipermag, is now available for magnetic amplifier reactors, transductors, current transformers, and other magnetic devices. The core is wound with an iron-nickel (50-50) alloy called Hipernik, whose excellent temperature stability, high remanent flux, and low coercive force results in a very nearly rectangular hysteresis loop. When shock resistance or encapsulation is required, the core is hermetically sealed in a nylon or aluminum case and filled with silicone oil or silicone grease as a damping medium. It will operate at a maximum of 125 and a minimum of minus 60 deg C. Nylon cases are said to be stable through these temperatures. Many sizes and weights are available.—Westinghouse Electric Corp., Pittsburgh, Pa.

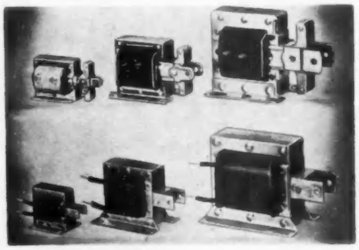
Circle No. 42 on reply card

SMALL BUT STABLE

A new line of plastic film capacitors, hermetically sealed in nonmagnetic tubes, features excellent stability and small size. Capacitance drift within a temperature range of minus 20 to plus 150 deg F will not exceed 0.1 percent. From minus 60 to plus 250 deg F, the deviation is still no greater

than 1.0 percent. Such stability is said to eliminate the need for compensating networks or ovens. As to size, the 1-mfd, 300-volt unit, for example, measures only 1 in. in diam by $2\frac{7}{16}$ in. long. Insulation resistance is high. Capicitors with tolerances of plus or minus 0.1 percent are used for integrator applications, and the entire line is used in timer, resonant, and discriminator circuits.—Electron Products Co., Pasadena, Calif.

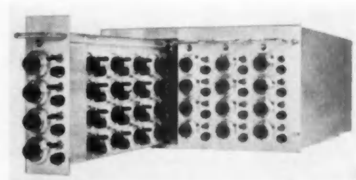
Circle No. 43 on reply card



AC SOLENOID

A complete line of custom-designed ac solenoids, now available for stock deliveries, consists of 17 models. Among the 34 different specifications: push and/or pull capacities up to 45 lb, sizes from $1\frac{3}{8}$ by $1\frac{3}{8}$ in. to 3 by 3 in., and stroke lengths up to 2 in. Double-shading coils provide high sealed pull without hammer or excessive ac hum. Rugged construction assures long service life under severe conditions.—Dormeyer Industries, Chicago, Ill.

Circle No. 44 on reply card



MANUAL-SET POT SYSTEM

By means of a unique packaging arrangement in this manually-set potentiometer system for electronic analog computers, 100 ten-turn, high-resolution potentiometers, each complete with a fuse and setup switch, are housed in a standard 19-in. relay rack only $10\frac{1}{2}$ in. deep. The assembly involves five drawers with 20 potentiometers per drawer; four are on the front panel, and 16 on one side of the drawer behind the panel.—Berkeley

NOW! A REVOLUTIONARY NEW CONCEPT IN PRECISION DIGITAL MEASUREMENTS OF AC, DC, Ohms and RATIOS

New E-I transistorized plug-in modules give maximum flexibility for custom applications with standard off-the-shelf modules.

This latest E-I development provides the maximum versatility in digital instrumentation. From a few basic modules a host of instruments can be constructed. Basic modules never become obsolete. To do new jobs, simply add new modules. Equipment can be easily kept current at minimum cost and engineering.

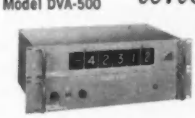
But versatility is only part of the story. These new modules also boast dramatically new engineering specifications, fully transistorized circuits and numerous other features which were incorporated as the result of our experience with more than 1,000 digital instruments in the field.

Your E-I representative has complete information on this latest E-I development. Ask him about it... today!

Any precision instrument for measuring DC, AC-DC, Ohms, DC and AC ratios can be constructed from these five basic units!

whether it be a DC digital voltmeter...

Model DVA-500

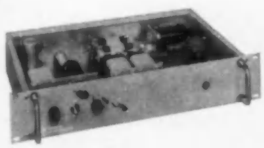


an AC-DC digital voltmeter...

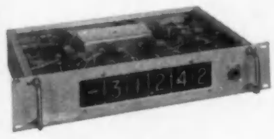
Model DVA-510

or a complete check-out system.

BASIC MODULES



Universal Power Module
Supplies all power and reference voltages for other E-I modules. Power and reference supplies and stepper drive amplifier are transistorized. Powers one or more modules. Automatic calibration; stability of 0.01% from 40° to 125° F.; input power: 115 volts, 50 to 400 cycles.



DC Switch Modules, 4 or 5 digits
Visual in-line read-out of digits, polarity, decimal point. All contacts accessible at rear panel connector. Front and rear panel input connectors. Power supplied by Universal Power Module.

DC Pre-Amp Module
Input: 1 range scale, gain of 10.
Output: 0.001 to .9999 volts.
Linearity: 0.01%.
Gain Multiplication Accuracy: 0.01%.
Input Power: 115 volt, 50 to 400 cycles.
Drift: 10 microvolts per hour.

AC – DC Converter Module
A fully transistorized AC – DC converter.
Accuracy: 0.1% of reading, or 2 mv.
Frequency Response: 30 to 10,000 cycles.
Range: .0001 to 999.9 volts.
Zin, AC: 1 meg. on the 1 volt scale, 10 megs. on other scales; 20 mmf.
Ranging: Automatic
Reading Time: 3 seconds, average.

Resistance Switch Modules, 4 or 5 digits
Contains balance circuit, bridge ratio arms. Provides visual in-line read-out digits, range. All contacts accessible at rear panel connector. Power supplied by Universal Power Module.

New short form catalog now available. Write for yours today!

ELECTRO INSTRUMENTS INC.
3794 ROSECRANS, SAN DIEGO, CALIFORNIA

Div. of Beckman Instruments, Inc., Richmond, Calif.

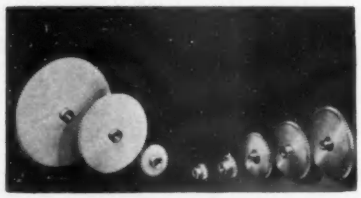
Circle No. 45 on reply card

NEW COLD JUNCTION

A new miniature reference junction unit, the AutoRef, provides constant-temperature reference at thermocouple cold junctions for demanding industrial applications. It is small and light, and resists severe shocks and vibrations. A compensating bridge design makes it extremely useful in situations where measured temperatures vary widely above and below ambient. A third voltage, continuously equal and opposite to the reference junction voltage, is added to the circuit so that only measuring junction voltages are detected.—Thermo Electric Co., Inc., Saddle Brook, N. J.

Circle No. 46 on reply card

ACCESSORIES & MATERIALS



FOR BREADBOARDERS

This company's line of standard electromechanical breadboard parts now includes these precision gears, available for stock delivery. Spur gears are 48- and 64-pitch, in tooth multiples of 8 and 10, with 14½-deg pressure angle and minimum and maximum pitch diameters of $\frac{5}{16}$ in. and 4 in., respectively. Gears have clamp hubs with ¼-in. bores. Gears for pitch diameter of 1 in. or less are of stainless steel and have a face width of $\frac{3}{16}$ in. Gears over 1 in. are aluminum and have a ⅛-in. face width. All are made to AGMA Class 2 standards. Spring and clutch gears, available in the same range of sizes, have somewhat larger minimum pitch diameters. Straight-tooth bevel and miter gears are available in $\frac{3}{16}$-in. and ¼-in. bore sizes, pin hub only.—Beckman/Helipot Corp., Newport Beach, Calif.

Circle No. 47 on reply card

NEW! FM Telemetering Discriminator*

ultra-stable

**Epsco Model FM-108 FM-to-Voltage Converter.*

Epsco's Model FM-108 crystal-controlled ultra-stable, all-channel discriminator presents a new *standard of accuracy* . . . better than an order of magnitude more accurate and stable than any other commercially available equipment . . . and with absolutely *no* adjustments! This new standard of FM data processing features:

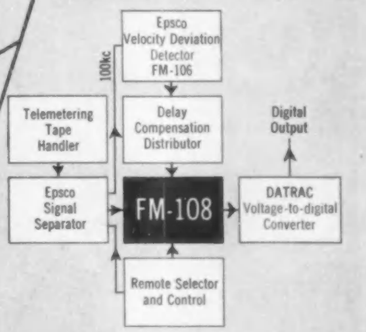
- **HIGH DYNAMIC ACCURACY:** Absolute accuracy is better than 0.05%, and the dynamic accuracy of the equipment from input to associated band-pass filter through the low-pass output filter is better than 0.2%.
- **LONG-TERM STABILITY:** 0.2% for life of equipment with no adjustments for zero drift, gain and line voltage variations, etc.
- **VERSATILITY:** Converter operates on any of 23 standard IRTWG telemetering sub-carrier frequencies from 400 cps to 70kc. Band switching may be accomplished remotely or by selector switch on front panel.
- **AUTOMATIC WOW and FLUTTER COMPENSATION:** With Epsco FM-106 Velocity Deviation Detector and Epsco CD-601 Velocity Deviation Compensation Distributor, errors from tape speed variations are reduced by a minimum of 35 db.
- **ZERO and 100% DATA CORRECTION:** Produces automatic compensation for variation of transmitting sub-carrier oscillator frequency and gain by a transistorized electro-mechanical servo feature.
- **DYNAMICALLY ACCURATE SELECTABLE LOW-PASS FILTERS:** A 5-pole filter utilizing precision wire-wound resistors and ultra-stable polystyrene capacitors in combination with chopper-stabilized d-c amplifiers provides:
  - Phase linearity deviation not exceeding 0.25 degrees over 90% of bandwidth.
  - Pass band flat within ±0.1% (0.01db) to F_c.
  - Minimum attenuation of 54 db of nearest beat frequency between sub-carrier channels.
  - A total of 62 different low-pass filter bandwidths selectable from 11 cps to 3490 cps.
- **PHYSICAL CHARACTERISTICS**

  SIZE: 10½" of space of standard 19" cabinet.

  WEIGHT: 29½ pounds.

  CONSTRUCTION: Constructed of 8 separate plug-in chassis assemblies containing electronic and magnetic components. All components are accessible on the standard layout forms.

Engineering data sheet available on request.



Epsco Model BF-601 Signal Separator units, each of which contains 23 band-pass filters, are available for separating the composite sub-carrier signal prior to input to FM Converter.

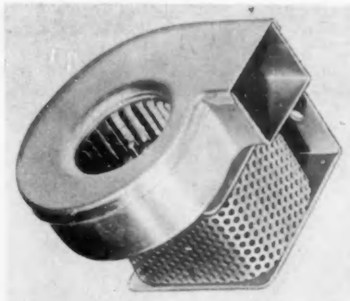
Complete FM telemetering receiving stations are available with or without wow and flutter compensation and zero and 100 percent correction features. Also available is the Epsco Model VCO-718 All-Channel Voltage-Controlled Oscillator for FM Discriminator calibration . . . which occupies only 3½ inches of panel space including power supply.

In the West, contact:
Epsco Service Corporation of California
1722 Westwood Boulevard
Los Angeles 24, California

Epsco *incorporated*

588 COMMONWEALTH AVE., BOSTON 15, MASSACHUSETTS

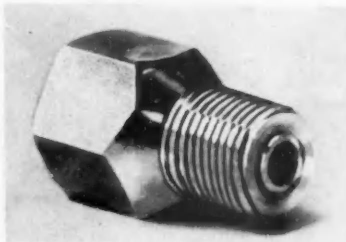
NEW PRODUCTS



MOVES 17 CFM

The blower pictured here, which weighs only 22 oz and measures 3½ in. wide by 2⅞ in. deep by 3¾ in. high, moves 17 cu ft of air per min at 3,000 rpm. It operates on a 115-volt, 60-cycle supply and draws only 10 watts. —Minarik Electric Co., Los Angeles, Calif.

Circle No. 48 on reply card



PRESSURE SNUBBERS

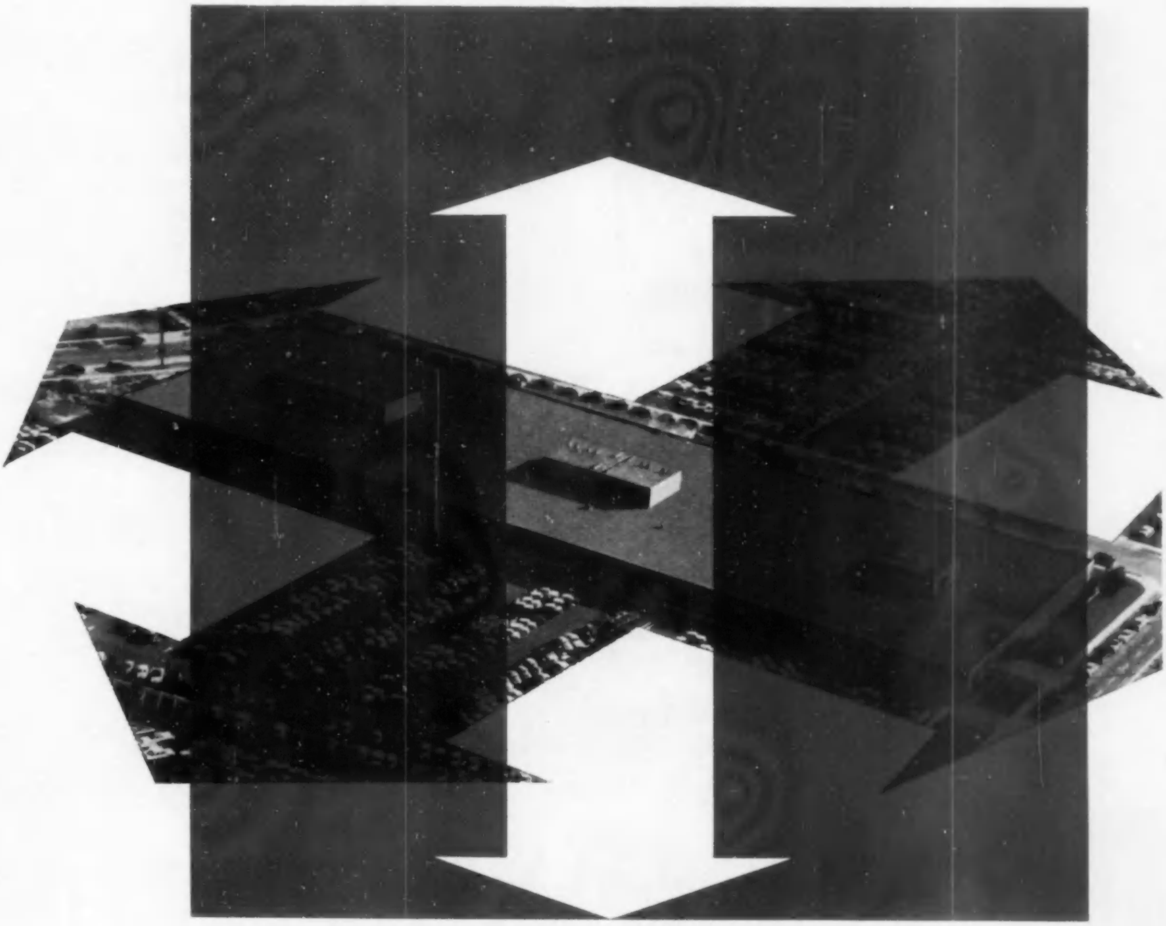
These new porous-metal models, designed to fill a need for small pressure snubbers in the aircraft, automotive, and refrigeration industries, are available with ⅛-in. NPT male and female connections. Like the earlier ¼-in. and ½-in. units, they are fabricated of brass, aluminum, or stainless steel; and in three porosities, for oil, water, and gases.—Chemiquip Co., New York.

Circle No. 49 on reply card

TEFLON DISCS

A line of standard-size Teflon discs, ranging in diameters from 4 to 18 in., was recently introduced. Stock thicknesses of 1/16 and ⅛ in. are available. Concerns now using sheet stock to make flat circular parts should be able to affect considerable savings by purchasing the disc nearest to their size requirements.—Allegheny Plastics, Inc., Coraopolis, Pa.

Circle No. 50 on reply card



NEW PRODUCTS

MINIATURE CLUTCH

A new, manually operated version of this company's miniature clutch is designed for engaging or disengaging parts of power-transmission drives such as tachometer or counter drives. Positive drive prevents any possibility of slippage. Several models are available, each equipped with end fittings for insertion at any point in power-transmission installations. – Barbour-Stockwell Co., Cambridge, Mass.

Circle No. 51 on reply card

FOR TAPE STORAGE

Shown is one of four new Mobile Magnetic Tape Trucks designed to house, protect, and transport magnetic tape reels. One type will accommodate 50 or 100 8-in. reels; the other will take the same number of 11-in. reels. All trucks are equipped with a separate locking device for each reel section.—Remington-Rand Div. of Sperry Rand Corp., New York.

Circle No. 52 on reply card

PLASTIC MAGNETS

A new flexible ferromagnetic plastic, trademarked Ferrotron, is now available in sample kits. Rod and tape form in a number of sizes can be ordered from stock. Kits are being offered to electronics designers to facilitate the investigation of new or improved concepts in circuit development. Prospects include good dielectric strength, constant magnetic permeability over a wide frequency range, and excellent moisture and temperature resistance.—The Polymer Corp. of Pennsylvania, Reading, Pa.

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(100) AERONAUTICAL TESTING. CDC Control Services, Inc. Bulletin No. G-102, 24 pp. Deals with the company's CompuDyne Control Systems for aeronautical research and test facilities. Describes how these systems provide dynamic rather than steady-state control. Applications covered include wind tunnels, engine tests, structural loading, and fuel-systems tests.

(101) RADIATION EQUIPMENT. Nuclear-Chicago Corp. Catalog Q, 64 pp. Presents a complete line of precision instruments for nuclear measurement. Type of equipment ranges from sample preparation aids to elaborate counting devices. Over 30 new products are introduced in this catalog. Descriptions are accompanied by photos, line drawings, and comprehensive specifications.

(102) PORTABLE RECORDER. The Bristol Co. Bulletin E1117. Describes a new weatherproof, self-contained, portable millivoltmeter-recorder for use in surveys of electrolytic corrosion and deterioration of underground structures. A bibliography on actual testing methods and their significance is also included.

(103) DATA RECORDING SYSTEMS. North American Instruments, Inc. Bulletin 105-A, 4 pp. Lists ranges and applications for a number of pressure transducers and accelerometers. Also contains a chart showing the principle characteristics of the company's variable reluctance pressure gage, comparing it with potentiometers and strain gages. A second chart covers magnetic tape recorders.

(104) FLOATED RATE GYRO. Norden-Ketay Corp. Bulletin No. 419, 4 pp. Gives general, pickoff, and motor characteristics of a new floated rate gyro. Large cutaway view points up salient features. Temperature, shock, and vibration conditions are also covered.

(105) MEASURING SYSTEM. Detroit Controls Corp. Bulletin B257, 4 pp. Contains a general description of the operating principles and applications of a nonelectronic signal generator system for measurement, indication, transmission, and control of a variety of process variables. Block and circuit diagrams illustrate the system's versatility.

(106) "PUNCHED TAPE STORY". Friden Calculating Machine Co., Inc. Booklet, 24 pp. Picture story shows how common-language punched paper tape, a byproduct of the Flexowriter machine, can integrate other office equipment, or reproduce documents on the same machine, automatically, at 100 words per min.

(107) SHUTOFF VALVES. Shutte & Koerting Co. Bulletin 8A. Pictures and briefly describes two automatic shutoff valves for oil, water, air, or other lines. Sheet also lists available sizes.

(108) EXPANDED-SCALE METERS. Beckman/Helipot Corp. Data Sheet 875, 4 pp. Contains photos and dimensions of eight typical expanded-scale voltmeters, both ac and dc. Last page lists 126 standard models with square, round, and rectangular cases, and gives range, accuracy, and center-scale voltage values of each.

(109) TRANSISTORIZED COMPUTER. Philco Corp. Brochure, 12 pp. Describes a new completely transistorized computer, the TRANSAC type S-2000. Explains how the all-transistor construction eliminates air conditioning, saves floor space, and accommodates readily-available input and output equipment. Diagram compares power consumption of transistor circuits with diode and tube circuits.

(110) THRUST STANDS. Hunter-Bristol Corp. Brochure, 8 pp. Explains the simple

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design and operating principles of custom-built engine test stands for thrust-measuring systems. Exploded view shows the clean construction of a typical stand.

(111) LONG-LIFE CAPACITORS. Industrial Condenser Corp. Catalog 1165, 12 pp. Presents the new line of Royalitic Long Life Capacitors, electrolytic units that feature low leakage currents and long shelf and operating life. Also contains some electrolytic capacitor data that should be useful to the design engineer.

(112) ELECTRIC THERMOSTATS. Robertshaw-Fulton Controls Co. Bulletin RT-803, 4 pp. Photos, specifications, and circuit diagrams are used in describing two electric thermostats for industrial equipment applications. Wiring diagrams show double-pole, single-pole, and three-phase hookups.

(113) GAS CHROMATOGRAPH. Beckman Instruments, Inc. Brochure, 4 pp. Contains a general description of the Model 220 Industrial Gas Chromatograph, an instrument designed to continuously monitor the critical components in a process stream. Schematic shows how the automatically times sampling system operates.

(114) TEST INSTRUMENTS. Panoramic Radio Products, Inc. Catalog Digest, 8 pp. Lists a complete line of standard test instruments, including telemetering test equipment and a number of new products. Tables and graphs accompany the descriptions and summary specifications.

(115) MAGNETIC AMPLIFIERS. Litton Industries. Product Catalog, 16 pp. Data and specifications on 400- and 60-cycle magnetic amplifiers are presented here, along with a number of typical ac and dc signal connections.

(116) GAGE ACCESSORIES. U. S. Gauge Div. of American Machine & Metals, Inc. Catalog No. 600, 4 pp. Describes a variety of accessories for gages, dial thermometers, and recorders. These include chemical attachments, flush-mounting assemblies, fittings, tools, and pulsation dampers.

(117) ANALOG COMPUTER. Donner Scientific Co. 4-pg. data sheet. Discusses the design, capacity, and accessories of the company's Model 3000 Analog. Complete prices, typical module combinations, and recommended computing facilities are also included.

(118) CONTINUOUS CO ANALYZER. Mine Safety Appliance Co. Bulletin No. 0702-1, 4 pp. Graphically explains the harmful effects of carbon monoxide and describes how the M-S-A CO Analyzer works, covering both the sample system and periodic calibration. Page 4 lists a number of specific applications.

(119) REPEAT CYCLE TIMERS. A. W. Haydon Co. Bulletin AWH RC201, 2 pp. Replaces page 3 of the company's current catalog, and contains details on the function of three basic-miniature Repeat Cycle Timers. Illustrations include a photo of the dc model and dimensional drawings, with overall and mounting dimensions tabulated.

(120) 10- AND 3-TURN PRECISION POTS. Beckman/Helipot Corp. Data Sheet 54-03, 2 pp. Contains life expectancy figures and noise ratings for series A (10-turn) and series C (3-turn), 1-13/16-in.-in-diam precision potentiometers, in addition to all previously published specifications on standard linear models.

(121) FOR LIGHTED PUSHBUTTONS. Micro Switch Div. of Minneapolis-Honeywell Regulator Co. Data Sheet 117, 2 pp. Shows a number of plastic buttons for lighted pushbutton switches. Shapes include round, hex, and square heads available in five different colors. Lamp data is included, though the company does not furnish lamps.

(122) ENVIRONMENTAL CABINETS. Webber Corp. Bulletin 2-57, 4 pp. Illustrates six different models of standard sub-zero industrial freezers for environmental temperatures from minus 225 to plus 350 deg F. Standard and optional features are listed as well as temperature ranges, capacities, and dimensions.

(123) FEED WATER CONTROL. Copes-Vulcan Div. of Blaw-Knox Co. Bulletin No. 1028, 4 pp. Describes the company's new Type P regulator for remote control of boiler feed water in stationary and marine service. Bulletin also discusses the primary elements and shows schematic system arrangements.

(124) TWO-CHANNEL RECORDER. Texas Instruments, Inc. Bulletin No. R-502, 6 pp. Gives specifications and features of TI's new Dual Recti/riter, a two-channel rectilinear galvanometer recorder.

(125) DIAPHRAGM FEEDER. Proportioneers, Inc. Bulletin 1913, 2 pp. Cites the principle features of the company's Model 1913 air- or water-operated chemical feeder. Operational data, installation, and mounting dimensions are covered.

(126) VARIABLE-SPEED DRIVES. Magnetic Amplifiers, Inc. Bulletin S-790, 4 pp. Contains general specs and engineering data on the Magne-Speed "Junior" variable-speed drives in fractional hp sizes from $\frac{1}{8}$ to 1/100 hp. Illustrations include a schematic and dimension drawings.

(127) GENERAL-PURPOSE RELAYS. RBM Div. of Essex Wire Co. Bulletin No. 1060, 8 pp. Gives details of construction and applications for both ac and dc general-purpose relays. Contact data are charted, along with maximum dimensions for front and rear mounting positions. Drawings also show the many contact forms available.

(128) REMOTE CHART PRINTER. Royson Engineering. Folder, 4 pp. Illustrates and describes the company's Identi-

charts, recorders that print on strip charts, from a remote point, the exact time or sequence conditions during process control or test work. Also covers related devices such as card printers and accessories.

(129) PLASTIC VALVES AND FITTINGS. Walworth Co. Bulletin, 16 pp. Describes a line of plastic (polyvinyl chloride) valves and pipe fittings that offer exceptional resistance to most salts, alkalis, and acids. Bulletin presents four pages of application tables on the performance of normal- and high-impact valves and fittings.

(130) RESISTANCE-MEASURING BRIDGE. Shallcross Mfg. Co. Bulletin L-19B. Describes seven resistance-measuring bridges covering dc measurements from 1 micro-ohm to 1 million megohms with tolerances of as little as 0.02 percent. Types illustrated range from general-purpose Wheatstone bridges for lab and field to special-purpose percent-limit bridges.

(131) ELECTRONIC RELAYS. RBM Div. of Essex Wire Co. Catalog No. 1050, 8 pp. Gives comprehensive engineering facts for many types of open and hermetically sealed electronic relays. Details include coil voltages, resistances, and wattages, contact forms available, and approximate weights.

(132) HIGH-TEMPERATURE ALLOYS. The Carpenter Steel Co. Booklet, 20 pp. Gives detailed descriptions of the engineering properties and fabrication characteristics of ten high-strength alloys for elevated temperature service. Technical information includes physical constants, mechanical properties at room and elevated temperatures, heat-treating data

(133) PULSE PROGRAMMING. Navigation Computer Corp. Brochure describes the technical features of transistorized pulse programming equipment. It offers descriptions, specifications, and illustrations of the individual units as well as input and output waveforms. Indexed for easy filing.

(134) BASIS WEIGHT CONTROL. Industrial Nucleonics Corp. Bulletin No. B-1657, 12 pp. Describes systems used to measure and automatically control basis weight of bond, publication, glassine, newsprint, kraft, and asbestos papers. A separate section covers weight control of such processes as abrasive coating, extrusion laminating, gumming, etc.

(135) THERMISTOR APPLICATIONS. Thermistor Div. of Gulton Industries, Inc. Bulletin No. T-100, 10 pp. Contains specifications and operating characteristics of wafer, rod, and bead thermistors. Applications table, page 3, lists typical problems, recommends types of thermistors to be used, and shows the circuitry required.

(136) MEASURING INSTRUMENTS. Brush Electronics Co. Condensed catalog. 24 pp. Sectioned for easy reference, the catalog covers a complete line of instruments for sound measurements, stress analysis, vibration analysis, and production testing.

(137) INSTRUMENT BEARINGS. Miniature Precision Bearings, Inc. Specification sheet No. 814. Covers a new-size, thin-section instrument ball bearing. Models are available with either single or double shield, with or without flange. Materials available are SAE 52100 and 440 stainless steel.

APPLICATION LITERATURE

NOTE: The following new bulletins and catalogs are available free of charge, but requests should be made by writing directly to the companies involved.

SILICON IN ELECTRONICS. Aries Laboratories, Inc., 41 East 42nd St., New York 17, N. Y. "The Relationship of Silicon and Its Properties to the Electronics Industry", a 20-page monograph, describes the characteristics of silicon in rectifiers, solar batteries, transistors, etc.

The author, D. R. Mason, first discusses the operating principles and reliability of semiconductor devices in general, then presents a detailed description of the interatomic structure and properties of silicon, pointing out certain analogies between the theory of electrolytic solutions and semiconductor theory. Arguments are advanced to show why silicon is considered the most versatile semiconductor material on the market today.

Finally, Mason gives a brief description of the various processes used in the manufacture of semiconductor devices.

TAPE WOUND CORES. Magnetic Inc., Butler, Pa. Catalog TWC-200, 30 pp. The first part of this comprehensive bulletin describes in great detail the advantages and construction features of the company's "Performance-Guaranteed" tape wound cores. Here also are presented all of the standard core sizes proposed by the AIEE Magnetic Materials Subcommittee, with complete dimensional data. Typical hysteresis and ac dynamic loops compared for My Mu 80, 48 Alloy, and Orthonol.

A design manual section gives detailed methods of dynamic testing, EI loop testing, dc testing, and core matching. Tables are devoted to basic units and conversion factors, properties of nickel-iron alloys, and magnetic values of these alloys. Curves show variations of magnetic properties with temperature and frequency changes.

A bibliography of books and papers is included near the back, along with a page on the characteristics of bobbin cores.

ELECTROMAGNETIC CONTROLS. Automatic Switch Co., Florham Park, N. J. Seven catalogs:

Catalog 57-S1 provides complete information on the company's automatic transfer switches. Included are 16 pages of engineering data, a wealth of application information, and price lists. 56 pp.

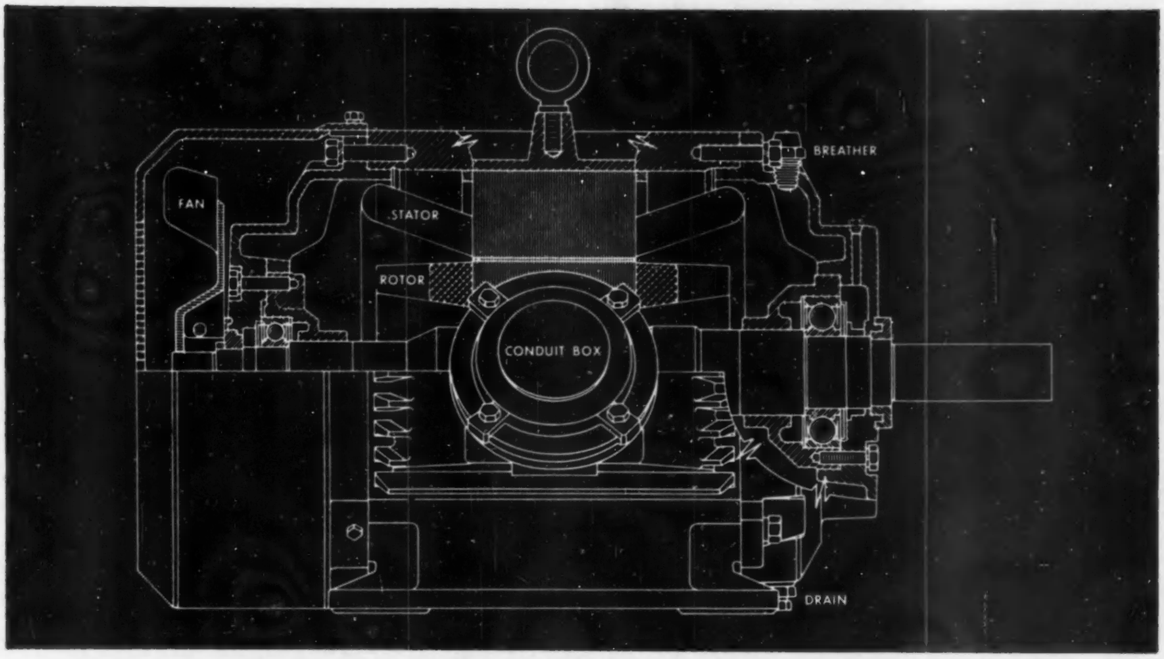
Catalog 57-S2 covers a complete line of mechanically held remote-control switches for power and lighting circuits. 34 pp.

Catalog 57-S3 describes magnetically held contactors for all normally-open and normally-closed classes of load. 28 pp.

Catalog 57-S4 lists standard and special-purpose relays, in magnetically or mechanically held models with unlimited pole combinations. 42 pp.

Catalog 57-S5 includes ac and dc solenoids, and Catalog 57-S6 describes ASCO electric plant controls such as paralleling, changeover, and alternating panels, load demand controls, etc.

Catalog 57-S, the complete Electromagnetic Control Catalog, combines the information in 57-S1 through 57-S6.



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Insuring facilities with electric motors in hazardous atmospheres is generally expensive or impossible without special motors. Reliance has developed a completely new, Underwriters' approved motor design, called explosion-proof, for hazardous locations. In fact this is the only motor design that meets all qualifications for class I, group D and class II, groups E, F and G without requiring modification.

This new motor incorporates all of the outstanding features of the standard Reliance Totally-Protected Motor. In addition, all Reliance Explosion-Proof Motors are built to corrosion-proof standards.

If you would like to have more information on what qualifies a motor for hazardous atmospheres, write for our new Explosion-Proof Motor Bulletin No. B-2409. B-1806

NATIONAL ELECTRICAL CODE CLASSES OF HAZARDOUS LOCATIONS

CLASS I—Those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures.

Group D—Atmospheres containing gasoline, hexane, naphtha, benzine, butane, propane, alcohols, acetone, benzol, lacquer solvent vapors, or natural gas.

CLASS II—Those which are hazardous because of the presence of combustible dust.

Group E—Atmospheres containing dust of aluminum, magnesium, or their commercial alloys.

Group F—Atmospheres containing carbon black, coal or coke dust.

Group G—Atmospheres containing flour, starch or grain dust.

RELIANCE *Totally-Protected* MOTORS

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(*Continued from page 52*)

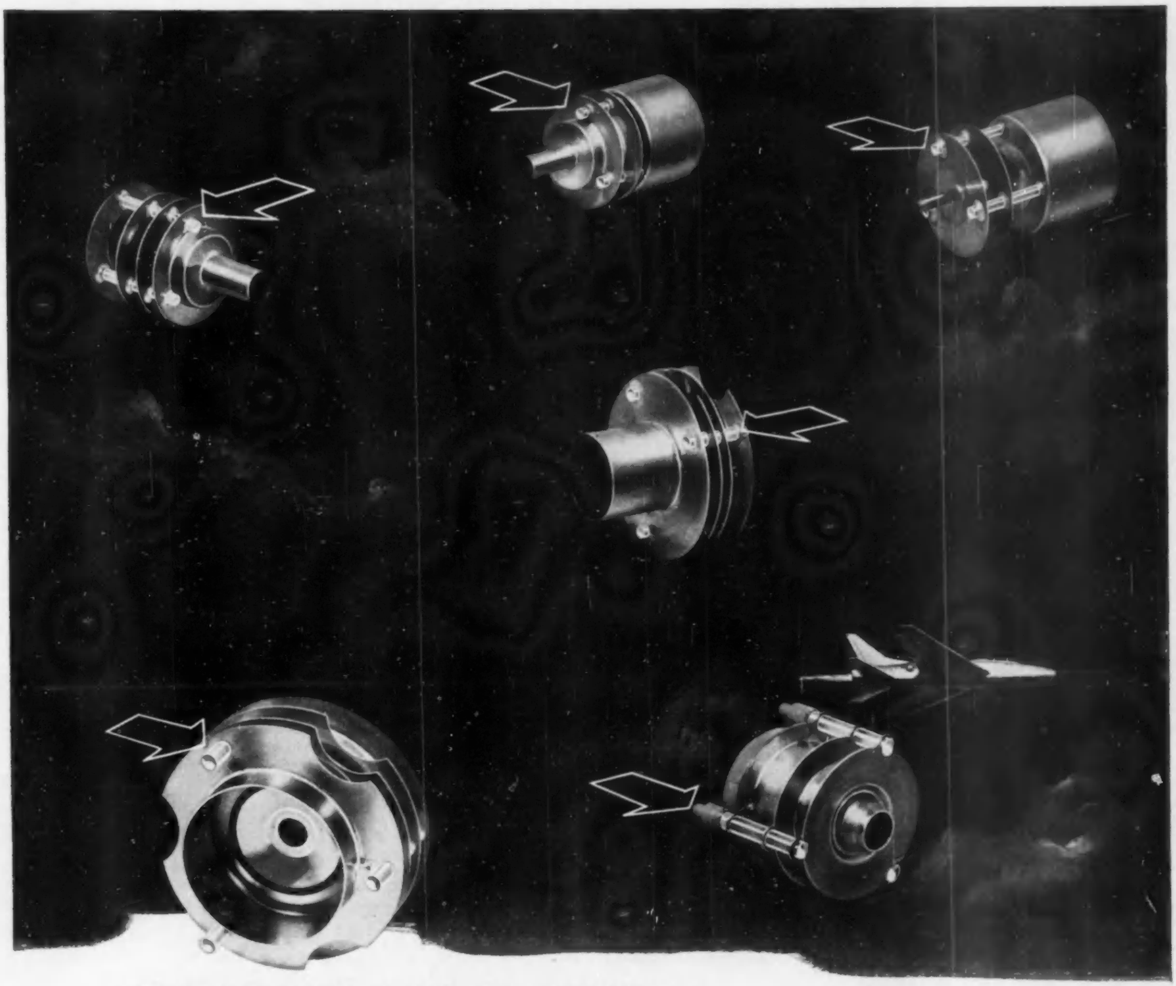
with Consolidated Electrodynamics (then Consolidated Engineering) as senior mathematician and supervisor of instruction. At CE he developed the initial subroutines and manuals for the Datatron computer. In 1955 he left to join ElectroData Corp. as southwestern regional manager. Austin has taught computer courses at Pasadena City College and the University of Michigan, and has applied for several patents for original work.

He is responsible for two new words in computer terminology: "Datics, the science which deals with the cataloging, analysis, processing, filing, and interpretation of real and theoretical data; the methods by which procedures, processes, and situations may be automatized", and "datatician, an expert in datics". With him in the new company are Anthony F. Marotta, manager of the Data Preparation Group; Robert L. McIntire, director of computing services; Dan W. Patterson, director of data-reduction services; Cloyd M. Roberts and Jon Vinson, dataticians, and John M. Ryan, director of data processing.

Other New Companies

Digitronics Corp., an independent consulting and R&D company organized by former employees of Underwood Corp.'s Elecom Div.—in Long Island City, N. Y. Although Underwood has just about definitely decided to give up manufacture of large-scale computers like Elecom 125 (CtE, May, p. 48), no real connection can be observed between this and the establishment of the new concern. "Elecom would have closed down anyway," is the way Digitronics' Vice-President Robert F. Shaw puts it, adding that the new firm grew out of an "offer" on the part of all Elecom people to go into business for themselves. No big computers will be manufactured by Digitronics—at least, not yet—though a contract with Underwood permits Digitronics to use part of the Elecom plant. Under terms of this contract, Digitronics takes over the production of lumped-parameter delay lines and some product-supply and service business connected with Underwood's small-computer program.

Cohu Electronics, Inc., which will "provide financial and business management for electronics manufacturing and development companies"—in San Diego, Calif. La Motte T. Cohu, who has his hands busy as president, chairman, and chief executive officer



of the new company, is also president and chairman of Kay Lab (which, incidentally, has changed its name to Kin Tel—see its annual report below). The corporation was formed, Cohu said, "because we feel sure that the techniques developed at Kay Lab are applicable to the entire electronics manufacturing industry. One of the first objectives of the new corporation will be to purchase other companies in the electronics field – the most rapidly growing segment of American industry." Cohu is also a former president of American Airlines, Trans World Airlines, Convair, and Northrop Aircraft, Inc.

More '56 Statements Filed

The filing of year-end financial statements by control firms continues. Those received since last month (CtE, May, p. 50) include:

Airborne Instruments Laboratory, Inc.: Sales up from \$9,255,950 to \$10,478,535; net earnings down from \$568,265 to \$306,925 (due principally to the absence in 1956 of substantial nonrecurring earnings recorded in 1955, and to a higher percentage of 1956 sales on a cost-plus-fixed-fee basis); working capital down \$183,445 to \$982,805; backlog up from \$7,100,000 to \$13 million (orders for electronics test equipment doubled to \$1,200,000).

Assembly Products, Inc.: Sales up 41 percent to \$1,444,085; earnings up 37 percent to \$82,518.

Borg-Warner Corp.: Sales up from \$552,192,430 to \$598,695,774; net income down from a record \$41,075,084 to \$35,841,952.

Consolidated Electrodynamics Corp.: Net earnings up 60 percent to \$1,283,263; sales up from \$17,124,429 to \$25,036,689; new orders up 47 percent to \$29,400,000; backlog up 79 percent to \$8,800,000. If the 40-percent growth rate of the past 11 years continues, said President Philip S. Fogg, Consolidated's annual sales could conceivably soar as high as \$90 million by 1960.

Friden Calculating Machine Co., Inc.: Sales up \$18,062,923 to \$50,624,940; net earnings up \$1,214,643 to \$3,591,625; capital nearly doubled from \$8,914,492 to \$16,054,527.

General Dynamics Corp.: Net sales up 52 percent to \$1,047,818,510; net earnings up 50 percent to \$31,946,995; backlog up 36 percent to \$2,195,000,000; net worth up from \$119,302,096 to \$142,146,793.

Kin Tel (formerly Kay Lab): Sales

FROM THE SMALLEST TO THE LARGEST UNITS...

the most desirable characteristics
ever offered in selenium rectifiers!

RADIO RECEPTOR *hcd** PETTI-SEL

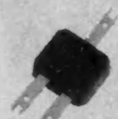
**high current density*

INDUSTRIAL TYPE SELENIUM RECTIFIERS

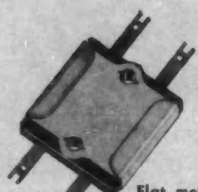
Made possible by the improved new vacuum process requiring no artificial barrier layer

Developed by Siemens Organization of West Germany, used extensively throughout Europe . . . and now manufactured exclusively in the U.S.A. by Radio Receptor Company.

the complete line ranges from...



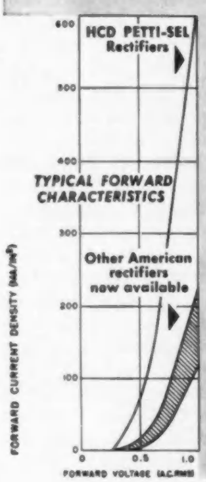
Plastic units, 7/16" x 7/16" x 3/32", single phase, center tap, 30V AC, 150 MA DC

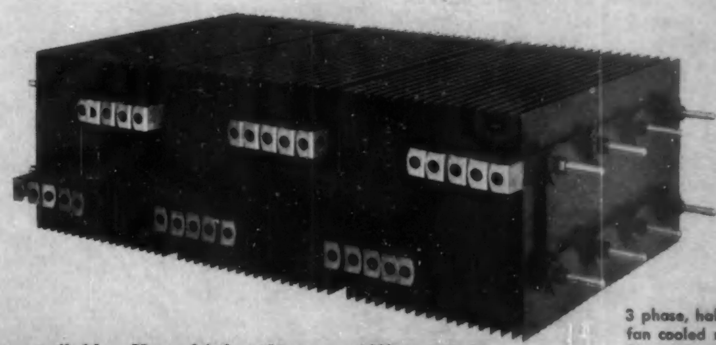


Flat metal rectifiers, 1 3/16" x 1 3/16" x 1/4", bridge, 30V AC, 200 MA DC

- **Better performance**
- **Estimated life 100,000 hours**
- **Lower forward voltage drop**
- **Suitable for high temperature applications**
- **Conveniently smaller cell sizes than conventional units of the same ratings**

...to the large space-saving





3 phase, half wave, fan cooled rectifiers, 8" x 16" x 24", 26V AC, 4500 amperes DC

Also available: Very high voltage rectifiers up to 296,000 peak inverse volts at 30 MA; Dwarfs — 5 MA up to 125V AC with resistive load; Cartridge types up to 17,000 peak inverse volts at 5 MA.

For complete information, submit your requirements today to Section C-6R.

R&R Co.

Semiconductor Division

RADIO RECEPTOR COMPANY, INC.

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Radio Receptor Products for Industry and Government: Selenium Rectifiers • Germanium Diodes
Thermatron Dielectric Heating Generators & Presses • Communications, Radar & Navigation Equipment

up 125 percent in 1956, from $1,343,000 to $3,332,000. Figures for the first two months of 1957 hint at even bigger and better things for this year. Total for the period: $1,281,645.

Lear, Inc.: Sales up 17 percent to $63,900,786; net earnings down from $2,115,811 to $1,977,799 (due mainly to lower profit margins and higher wages and material costs); backlog up 21 percent to $65 million; net worth up 16 percent to $11,459,568; working capital up 47 percent to $10,450,741.

Servomechanisms, Inc.: Net profits up 40 percent to $615,606; net sales up 46 percent to $18,138,280.

The Swartwout Co.: Net profit up to $135,685; sales up from $4,175,418 to $4,864,177.

Fattenings

Photographic Products, Inc., of Anaheim, Calif. (specialized cameras and other photographic equipment, automatic timing devices) to **Coleman Engineering Co., Inc.**

Kama Instrument Corp. of Mineola, N. Y. (pickoff units, potentiometers) to **The Narda Corp.**; Stuart Casper, Narda's vice-president of engineering, and Donald R. Robertson, chief of production for Kama's step attenuators and wave meters, become, respectively, general manager and plant manager of the new subsidiary.

William Miller Instruments, Inc., of Pasadena, Calif. (dynamic recording and data-processing equipment) to **Consolidated Electrodynamics Corp.;** Edwin M. Graham, Miller's executive vice-president and treasurer, is general manager of the new Miller Div.

Sessions Clock Co. of Forestville, Conn. (electric clocks and clock movements) to **Consolidated Electronics Industries Corp.**

U. S. Flare Corp. & Associates of Pacoima and Saugus, Calif. (rocket-ignition systems, missile-tracking systems, and pyrotechnic and high-explosive ordnance items) to **Atlantic Research Corp.**

Lima Electric Motor Corp. to **Consolidated Diesel Electric Corp.**

Westronics Co. (electronics testing) by **Electromation Co., Inc.,** which will operate Westronics as a division.

Magne-Head Electronics Co. of Los Angeles (recording heads for electronic computers and other automatic equipment) to **General Transistor Corp.,** which has renamed it **General Transistor Western Corp.**

Coote & Jorgensen, Ltd., of Sydney, Australia (automotive parts) to **Borg-Warner Corp.**

IMPORTANT MOVES BY KEY PEOPLE

Assembly Products' President Still Cracks Books At Night

John D. Saint-Amour, who was good enough with the French horn to play in nationally known dance bands, proved when he came to Assembly Products, Inc., in 1948, as a meter-repair man, that he knew how to handle other kinds of instruments just as well. He rose so fast—from chief of a meter-assembly line through production superintendent to vice-president in charge of engineering—that his recent election to president of the company found him still going to night school.

Young (31) Saint-Amour got his start winding armatures for Reliance Electric & Mfg. Co. during his high-school summers. Then for a few years came jobs calling for the French horn. Soon after he joined Assembly Products, he applied himself to perfecting various electrical and mechanical details of the company's contact meter-relay, an item that accounts for approximately half of all sales today. Out of this work came numerous electrical patents. These days Saint-Amour is attending Fenn College; before that, however, there was Case Institute and Cleveland College. You could say he has tasted just about all Cleveland has to offer in the way of education.

Another Fenn "student" recently promoted by Assembly Products is Robert H. Pugsley, formerly assistant manager of sales, who becomes vice-president and sales manager. Bradley R. Thompson, who has been president and now is chairman of the board, explained that a big reason for both changes was to rechannel some of his administrative duties. This, he said, would allow him to give more time to several new products recently developed at the company's Desert Hot Springs (Calif.) plant.

Other Important Moves

▶ **Alexander Greenfield** comes to Fischer & Porter Co. from Daystrom Instrument Div., where he has been director of R&D, to fill a research gap caused by the promotion of **Nathaniel Brewer,** the former vice-president for R&D, to vice-president for technology, a policy-making post. Greenfield, whose title will be director of research, development, and engineering, has had additional research experience with Bendix Aviation and the Remington-Rand Institute of Advanced Research. Projects under his supervision have had to do with computers, nuclear

J. D. Saint-Amour

Alexander Greenfield

K. P. Bowen

W. W. Johnston

D. C. Webster

N. C. Anderson

This installation in the De Laval Steam Turbine Company in Trenton, N. J. demonstrates how fast load changes, caused by turbine tests, place a grueling load on this pressure controller reducing station for makeup. In the words of the power plant engineer: "The control stability is good and the controller does the job well."

Leslie Pressure Pilot

Narrow Band Pressure Control with Stability

Wide band stability and narrow band proportional control are uniquely combined in the Leslie Control Pilot without need for extra mechanisms to correct for over-sensitivity.

While the pilot responds to small, *definite* pressure changes, it "sorts out" and "ignores" the small, spurious* disturbances common to most control systems. Since it does not follow nor magnify these disturbances, cycling and hunting are eliminated. It is ideal for systems with short lag factors.

*not directly related to process variables but resulting from pipeline friction and turbulence.

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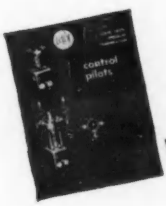
The "designed-in" stability and high capacity of Leslie Pressure Control Pilots also eliminates costly "extras" . . . there is no need for automatic reset, valve positioners or filter-type air sets. You get stable, reliable control *without* fussy adjustments and with *ordinary* plant air or water for the operating medium.



Send for Bulletin 5303 that gives complete technical data and typical application sketches for the Leslie Pressure Control Pilot.

MORE INFORMATION

Ask your Leslie engineer to give you the complete story of the exclusive features that make Leslie Controllers ideal for straight pressure control problems. He's listed in your classified directory under "valves" or "regulators". Send for bulletin described at left.

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WHAT'S NEW

instrumentation, telemetering, and guided missiles.

▶ **Kenneth P. Bowen,** the new general manager of Summers Gyroscope Co., has been vice-president for manufacturing and material for Northrop Aircraft, Inc., and assistant general manager for Fairchild Corp.'s Aircraft Div.

▶ **Warren W. Johnston,** who has been promoted by Panellit Service Corp. to manager of its Systems Div., came to the company a year ago from the Advanced Development Div. of Avco Mfg. Corp., where he had been chief of instrumentation research.

▶ **Donald C. Webster,** chief engineer and director of engineering for Librascope, Inc., has been elected vice-president. A 14-year-man with Librascope, Webster has also been with the Naval Ordnance Test Station and the American Petroleum Institute (as a research fellow).

▶ **Norman C. Anderson,** who takes over as vice-president in the Photoconductor-Transistor Div. of Electronics Corp. of America, joined the company in 1949 and most recently was manager of PTD. He has also done semiconductor research for the National Research Defense Council and the Navy.

▶ New manager of American Machine & Foundry Co.'s Raleigh (N. C.) Laboratory is **James A. Bolton,** formerly acting manager of the laboratory's battery unit, who replaces **Haywood C. Smith,** named technical manager in the R&D Dept. of the Engineering Div. in New York. Before coming to Raleigh, Bolton served as assistant manager of the company's Nuclear Engineering Laboratory in Greenwich, Conn. He joined AMF in 1941.

▶ Westinghouse Electric Corp. has given new status to its commercial atomic power activities, those concerned with the development, design, and sale of commercial nuclear reactors. The operation now has its own Atomic Power Dept., located at Pittsburgh, and a new manager, **Robert L. Wells,** formerly executive assistant to the vice-president in charge of the Aviation Gas Turbine Div. Wells, who succeeds **Carroll V. Roseberry,** named a vice-president and manager of the midwestern region, joined the company in 1940.

▶ **E. A. Link's** election to the new post of vice-chairman of the board of General Precision Equipment Corp. and to the GPE executive committee is viewed as a sign that GPE is planning to give added attention to automatic aerial navigation, flight control, and air traffic control through its sub-

sidiaries, of which Link Aviation, Inc., is one. Link is founder and chairman of the subsidiary, and the originator of aerial trainers and simulators. His work in this area has brought him many honors, including the Exceptional Service Award, the highest award the Air Force can bestow on a civilian.

► Two new appointments by the Stromberg-Carlson Div. of General Dynamics Corp. involve **Royal Weller,** formerly chief scientist at the Naval Air Missile Test Center, Point Mugu, Calif., named vice-president in charge of engineering, and **William G. Alexander,** formerly head of high-resolution radar at Westinghouse's Air Arm Div.

W. G. Alexander

Royal Weller

in Baltimore, named chief engineer at San Diego. Before going to Point Mugu in 1949, Weller was chief of the Engineering Dept. and in charge of all development work for the Naval Ordnance Laboratory at Silver Spring, Md. He is a fellow of the American Physical Society. Alexander had prior experience as director of engineering for American Machine & Foundry Co.'s Electronics Div.

► Arnoux Corp. has a new executive vice-president and director of research, and a new vice-president for engineering. The first is **Richard W. Hodgson,** the second **Walter Y. Fish.** Hodgson has been in the aircraft and missile instrumentation field for 17 years, the last five with Arnoux. Fish, who takes Hodgson's former post, has been Arnoux's chief engineer. His experience dates back 15 years.

► New chief engineer of Southwestern Industries, Inc., is **Charles Bodey,** formerly assistant to the vice-president of research for Standard Coil Products. Before that he was director of engineering for Minneapolis-Honeywell's Appliance Controls Div. in Los Angeles.

► A team of GE specialists has been appointed to manage the company's weapons systems research programs in the Missile & Ordnance Systems Dept. The team, part of the Aerosciences Laboratory force in Philadelphia, consists of: **Joseph Farber,** aerophysics; **Bernard Levine,** preliminary design; **M. A. Lifset,** administration; **E. A. Luebke,** the GE Research Laboratory;

Clifford Mannal, aerodynamics; **L. R. McCreight,** material studies; **J. O. Powers,** aerothermodynamics; and **F. J. Willig,** special projects.

▶ The new chief engineer and product manager of Electronic Specialty Co.'s RF Systems & Components Div. is **William R. Martin,** formerly in charge of the Radiating Systems Group of Lockheed Aircraft Corp. Under the new chief, the company is completing its new antenna pattern measurement range and expanding its RF Engineering Group. Martin is a senior member of the IRE.

▶ **John K. Gossland,** formerly with Hoffman Laboratories, has been named executive vice-president and general manager of Electromation Co., Inc. His field is radar, missiles, and nuclear physical instrumentation.

▶ Beckman Instruments' Scientific Instruments Div. has appointed **Bruce Johnson** chief manufacturing engineer for data and control systems at its new Anaheim, Calif., plant. He has had previous experience with General Motors' AC Spark Plug Div. and Beckman's Helipot Div.

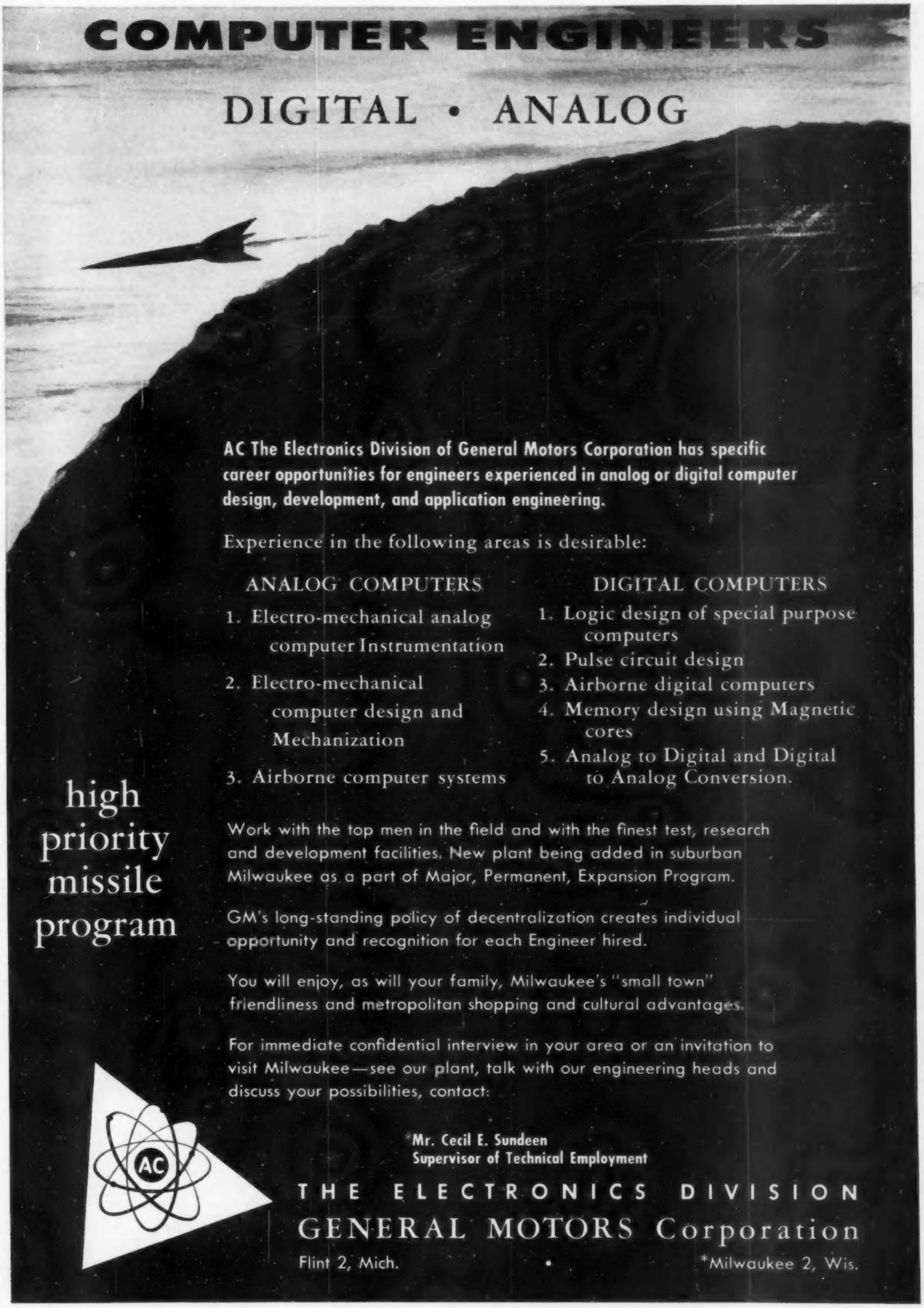
▶ **Robert G. Bryson,** one of the founders of Dynamics Research Associates, has been named assistant general manager of this Universal Match Corp. division. Before the establishment of DRA, Bryson was a research engineer in automatic flight controls at Boeing Airplane Co.

▶ **Richard D. Hanson,** the new manager of manufacturing for Donner Scientific Co., was formerly with Infra Electronics Corp. in the same capacity.

▶ International Resistance Co.'s Computer Components Div. has a new manager. He is **Frank G. Daveler,** who has been with IRC since 1950 as chief design engineer, and more recently as chief mechanical engineer. He also has managed Fischer & Porter Co.'s Data Processing Div.

▶ **George P. Brubaker,** the president of Brubaker Electronics, Inc., a recent acquisition of Telecomputing Corp., has been named president of the parent concern. In his new capacity, he will coordinate all divisions and subsidiaries of Telecomputing, including his own company, which he will continue to head.

▶ Cargill Detroit Corp has named **Avrel Mason,** formerly chief engineer, general manager of a new automatic gaging and size-control division. His successor is **Belding H. McCurdy.** Mason came to Cargill in 1954 with experience gained at Bendix Research Laboratories in Detroit, Detroit Tur-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3. Airborne computer systems
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2. Pulse circuit design
3. Airborne digital computers
4. Memory design using Magnetic cores
5. Analog to Digital and Digital to Analog Conversion.
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bine Co., and Fairchild Engine & Airplane Corp. McCurdy, a new face at Cargill, has been with Hancock Mfg. Co. as executive engineer.

► Convair's new Astronautics Div. has promoted several key men, including **Hans R. Friedrich** (CtE, April, p. 19), formerly chief of the Flight Mechanics Section, who becomes assistant chief engineer for development, succeeding **Mortimer Rosenbaum.** Others elevated: **J. R. Dempsey,** head of the Atlas missile program since 1954, to division manager; **K. J. Bossart,** formerly chief engineer, to technical director;

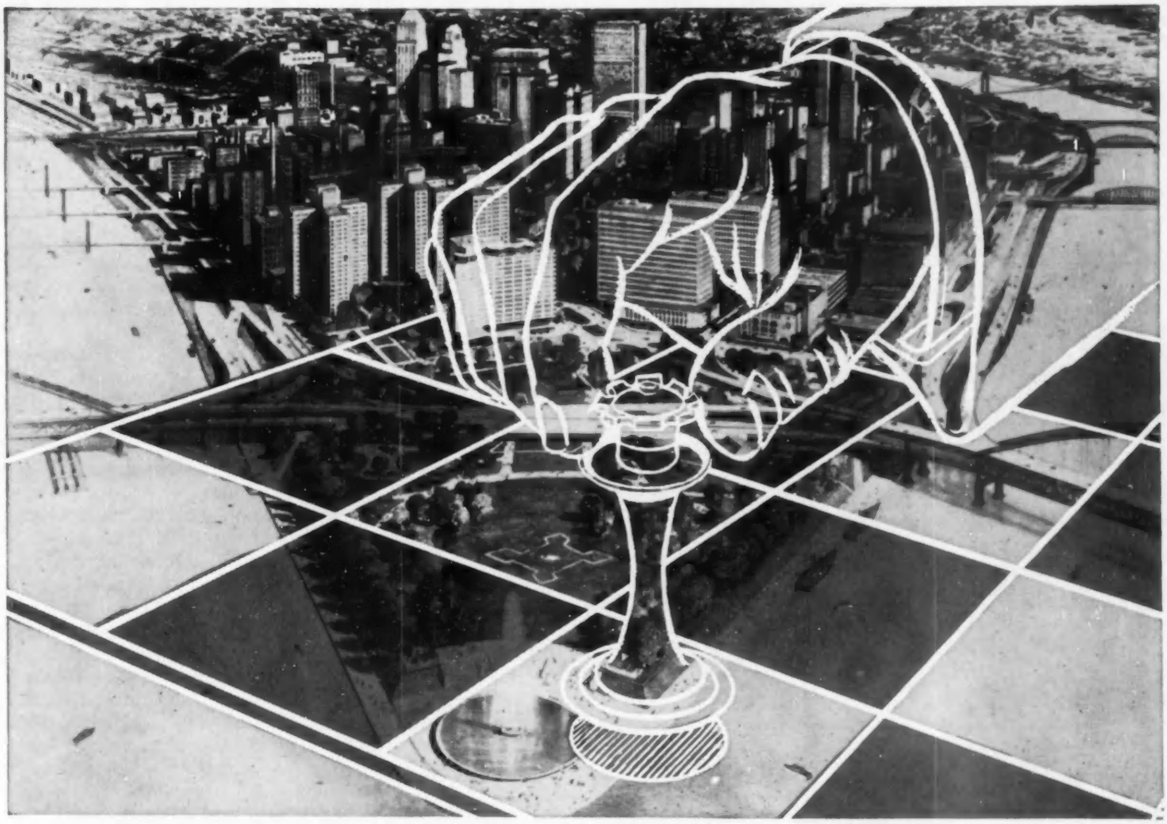
K. J. Bossart

M. Rosenbaum

Rosenbaum, to chief engineer; **Krafft A. Ehricke,** formerly chief of preliminary design and systems analysis, to assistant to the technical director; and **W. H. Schwidetzky,** formerly chief of flight performance and analysis, to chief of computers and simulation. New additions to the division are: **W. W. Withee,** formerly assistant chief of flight test at Convair-San Diego, named assistant chief engineer for testing, and **L. L. Lowry,** formerly chief of operations analysis at San Diego, named chief of systems analysis.

► Advance Industries, Inc., the former Ultrasonic Corp. of Cambridge, Mass., has appointed **Frank F. Kates,** an authority on guided missiles, fire control, analog computers, and infrared detection, as director of R&D. Kates, an engineer with a PhD in electro medicine and neuron electrical equivalents, directed the development of fire-control systems for Hughes Aircraft Co. and worked on missiles and analog computers at Boeing Airplane Co., where he was supervisor of the Physical Research Laboratories.

► **James E. Dallas,** who is credited with the development of the first practical continuous moisture detector for the lumber industry, has rejoined Plywood Research Foundation as development engineer. He left the company in 1949 to become chief engineer of Laucks Laboratories, Inc., of Seattle, Wash. His electronic detector is now in wide use in plywood and lumber mills and in some applications of paper manufacture.



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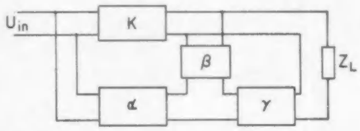
ABSTRACTS

Reducing Distortion

From "A New Compensating Method to Reduce the Nonlinear Distortion in High-Power Amplifiers" by A. A. Gorbachev. "Radiotechnika" (Russian), No. 4, 1956.

The distortion compensating method for power amplifiers is based on a circuit proposed by D. V. Ageev in 1954. The circuit is shown below in block diagram form.



For complete compensation of nonlinear distortion, it is necessary to realize two sets of conditions

$K\beta = -\alpha$

$\beta\gamma = -1$

The author analyzes the action of the system when these conditions are not met and the resulting improvements when they are met. Experimental checks performed on a 50-watt power amplifier revealed that the linearity of the system was improved by a factor of 10 over a wide range of audio frequencies. Also, the output impedance was shown to be very small.

Gorbachev recommends this method of nonlinear compensation for the high-power amplifier and, when the usual negative feedback is impractical because of large phase shifts in signals, for the overall nonlinear amplifier.

Generating Functions

From "Design of Diode Function Generators" by A. D. Talanzef. "Automatics and Telemechanics" (Russian), No. 2, 1956.

This paper describes new diode-element connections that may be used for generating functions in dc analog computers. The author shows that potential-grounded diodes reduce by 30 percent the total number of resistors needed and considerably simplify the design of the diode system for generating a given function.

One electrode of the diode is always connected to a virtually grounded point of the operational amplifier and the voltage of the other electrode becomes zero when the diode starts conducting. In Talanzef's proposed circuit one voltage divider adjusts both the transfer characteristics and the bias voltage, thus eliminating individual bias supplies.

All diode elements are classified into two groups: off-on and on-off operation elements. The paper discusses the best applications for each group, and presents a practical procedure for designing nonlinear circuits to represent a given function.

M. Mamon

Character Recognition

From "The Design of a Logic for the Recognition of Printed Characters by Simulation on the IBM 650 MDDPM" by E. C. Greanias, C. J. Hoppel, M. Kloomok, and J. S. Osborne, IBM. Paper 26.5, presented at the Institute of Radio Engineers National Convention, New York, March 18-21, 1957.

Inventors have been trying for more than 30 years to develop machines to recognize and read printed matter. The usual procedure has been to build a model, test it, observe its limitations, and then build an improved model. This approach has proved costly and time consuming. In general, the early recognition schemes did not detect relatively subtle differences between degraded characters which must be seen for accurate recognition. To sense such characters, many more logical operations on highly detailed information are required than the early schemes employed.

The design of logical criteria for the recognition of printed characters can be greatly expedited by using a high-speed digital computer, such as the IBM 650 magnetic drum data processing machine, to obtain information regarding the effectiveness of the proposed criteria when applied to realistic characters. In the simulation discussed here, the data fed to the computer represented the output signals from a suitable scanner when a wide range of characters was serially scanned with a fine spot of light along closely spaced vertical lines. Each vertical scan was divided into subintervals designated "black" or "white" in accordance with the reflected signals. Binary data for each scan were coded into three decimal digits which designate the number, size, and position of the black areas in the scan. The first digit related to the number and proportions of the black areas detected, the second digit to the change in altitude of the top of the character relative to a selected earlier scan, and

the third to the distance between extreme black areas on the scan.

The entire sequence of coded scan information constituted an abbreviated signature of the character. Recognition was achieved by comparing the coded sequence to a set of prescribed sequences which define the recognition criteria.

Basic input data for the simulation were obtained by scanning several thousand specimens with a laboratory flying-spot scanner and storing the resulting binary scan data in punched cards. Performance of a character recognition system is dependent on the quality distribution of the specimens. To assure an adequate distribution, the inked ribbons used to produce these specimens were operated for 150 percent of nominal life and identical samples were taken at equal intervals throughout this period. In addition, three standard types of paper were used, white, clear manila, and a manila with small dark fibers which tended to introduce random spots in the character background.

Coding definitions were applied by a program written for the 650 and the coded scan information was also permanently stored in punched cards. The proposed logical circuitry for comparing sequences of coded scan information to prescribed sequences was simulated on the 650 in a manner that expedited testing, modification, and retesting. The feasibility of this recognition scheme was established and the final design determined in considerable detail by simulation prior to construction of experimental models.

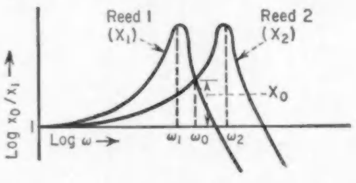
Resonating Reeds

From "Dynamic Response Study of a Mechanical-Hydraulic Frequency Discriminator Governor" by C. C. Christianson, General Electric Co. (now with Arthur D. Little, Inc.). Paper number 57-IRD-14, presented at the ASME Instruments & Regulators Conference, Evanston, Ill., April 8-10, 1957.

The mechanical-hydraulic governor described and analyzed in this paper is based on frequency discrimination of two resonant reeds. The reeds are driven at a constant amplitude, variable frequency from the unit to be controlled, and resonate as shown in the figure on page 215.

When the speed of the governed unit changes from nominal frequency, equivalent to ω_n in the figure, the reeds vary the flow through two nozzles, so that an unbalance force shifts

the position of a spool in a valve (also part of the governor). The flow rate of oil from the valve is proportional to the deviation in desired frequency. The flow then becomes a corrective



signal to adjust the frequency of the governed device. Essentially, then, the governor detects the reeds' unbalance displacement amplitude from X_o due to a load change or disturbance on the regulated unit and makes a corresponding correction.

After a brief explanation of governor operation, Christianson devotes the rest of his paper to a mathematical analysis of the dynamics of the governor and a comparison of this analysis with actual test results.

Shorties from IRD

From "An Analog Study of a High-Speed Recording Servomechanism" by J. W. Schwartzenberg (Paper No. 57-IRD-9). Schwartzenberg takes into account friction, backlash, velocity limiting, motor characteristics, carrier frequency effects, and frequency spectrum of signals in his study of a recording servomechanism. He gives their actual characteristics and tells how they were set up in the analog study. With the analog simulation he was able to adjust the input filter, gear ratio, and two types of damping (passive lead-lag network and absquare).

From "Dynamic Study of an Experimental Pneumatic Process-Pressure Transmitter" by E. F. Hochschild (Paper No. 57-IRD-7). The author analyses his pneumomechanical device to uncover and explain some obscure dynamic effects—compliance and output tubing on pilot valve. He found system changes which would most effectively produce faster dynamic response, minimize the variation due to tubing load, and suppress the pilot-valve nonlinearity. Results illustrate the necessity for an accurate knowledge of the system, and show that analytical and test work, though independent, must proceed hand-in-hand.

From "A Linear, Force-Input, Pneumatic Amplifier With Fast Response Characteristics" by T. E. Hoffman (Paper No. 57-IRD-4). Hoffman first made an analog study to determine the best configuration for the application of a pneumatic amplifier as a torpedo depth controller, then showed the analysis and design of an actual model based on the study.

NEW BOOKS

Controlling Turbines

REGULUNG VON DAMPF-UND GASTURBINEN (CONTROL OF STEAM AND GAS TURBINES) *by I. I. Kirillow. 396 pp. Published by Verlag Technik, Berlin, Germany, 1956, 30DM. (approximately $12.00).*

This German translation of a book by the well-known Russian expert on speed control of turbo machinery extensively and systematically presents the modern theory of control engineering as it pertains to high-speed steam and gas turbines. Special emphasis is placed on a detailed analytic study of the engineering problems of oscillation and vibration. The associated control systems and the structural properties of the elements of these systems are included as part of the general problem of machine-control theory.

Applying Information Theory

INFORMATION THEORY AND ITS ENGINEERING APPLICATIONS *by D. A. Bell, reader in electromagnetism in The University of Birmingham, England. Edition 2, 174 pp. Published by Sir Isaac Pitman & Sons, Ltd., London, England, 25 shillings; sold in U. S. by Pitman, 2-6 West 45th St., New York 36, N. Y. $5.00.*

The first edition of this excellent book, published in 1952, stated that its purpose was to make available to the working engineer in communications work and allied fields the essential theories published since 1948. Although information theory finds its prime usefulness in communications engineering, that portion of it which is concerned with Wiener's optimum linear filtering theory is of interest to control engineers. In fact, a considerable number of papers in this area have appeared in the control-engineering literature in the last several years and interest is still growing.

Eight well-rounded chapters here set out the basic concepts of information theory: 1. Introductory—Binary Digit Measure of Information; 2. Entropy and Information; 3. Band-width and Signalling Speed; 4. Signal-to-Noise Ratio—the fundamental aspects of coding; 5. Coding; 6. Decoding—various procedures for transmitting information, ranging from telegraphy and telephony to radar and television; 7. Practical Application of the Theory—a lucid introduction to optimum filtering, and 8. Wiener's Theory of Filtering.

The second edition clarifies certain

NEW BOOKS

points of theory, enlarges the chapter on coding, and adds the chapter on decoding. The last covers the possibilities and difficulties of making physical equipments which will actually effect the operations described by the mathematics, particularly as to recognition of the signal message content.

Five appendices (including one giving a lucid account of the parallelism between entropy and information and a brief introduction to the two-sided Fourier transform), prefaces to the first and second editions, and a subject index complete the volume.

This book should prepare the control engineer who wishes to go further into information theory, to read the somewhat more advanced text by Stanford Goldman, *Information Theory*, Prentice-Hall, Inc., New York, 1953, 385 pp.; and, after this, the recently-published, well-written, high-level text by Leon Brillouin, *Science and Information Theory*, Academic Press, Inc., New York, 1956, 320 pp., \$6.80. With these three books on basic theory behind him, the periodical literature on information theory and "statistical" analysis should cause the control engineer little difficulty.

Covering the Human Element

INFORMATION THEORY, *edited by Colin Cherry. Proceedings of the Third London Symposium, 401 pp. Published by Butterworths Scientific Publications, London, England; sold in U. S. by Academic Press, Inc., 125 East 23 Street, New York 10, N. Y. \$11.50.*

These proceedings of the third international conference on information theory comprise some 40 papers (three given as summaries) which range from lengthy treatments on basic theory to relatively short accounts of applications in practice. Subjects treated, optics, television, taxonomy, linguistics, machine translation of languages, semantics, physiology, psychology, and other areas are classified under the broad headings of fundamentals; coding, taxonomy, etc; language translation and mechanical translation; meaning and the human senses; and behavior and its mechanisms. Opening remarks by Cherry (professor of electrical engineering at the Imperial College of Technology, London, and one of the foremost British workers in the subject), a table of contents, and an index round out the volume.

Although these proceedings have limited interest to control engineering per se, those engineers who must incorporate a human element into their systems work will find profit here. Attention is directed particularly to the absorbing paper by J. D. North, "Application of Communication Theory to the Human Operator."

Thomas J. Higgins
Madison, Wis.

WHAT'S AHEAD: MEETINGS

MAY

National Telemetering Conference, (inspection trip to White Sands Proving Grounds), Hotel Cortez, El Paso, Tex. May 27-29

Institute of Radio Engineers, First National Symposium on Production Techniques, Hotel Willard, Washington, D. C. June 6-7

JUNE

American Society of Mechanical Engineers, Semi-Annual Meeting, Hotel Sheraton-Palace, San Francisco June 9-13

Institute of Radio Engineers, National Conference of Professional Group on Military Electronics (some sessions classified "confidential"), Sheraton-Park Hotel, Washington, D. C. June 9-15

Instrument Society of America, Third National Symposium on Instrumental Methods of Analysis, University of Chicago June 13-15

Association for Computing Machinery, Twelfth Annual Meeting, University of Houston, Houston, Tex. June 19-21

American Institute of Electrical Engineers, Summer General Meeting, Sheraton-Mt. Royal, Montreal, Quebec, Can. June 24-28

British Institution of Radio Engineers Convention, Theme–"Electronics in Automation", University of Cambridge, (9 Bedford Sq., London, W. C. 1) June 27-July 1

AUGUST

Institute of Radio Engineers, Professional Group on Automatic Control, Fairmount Hotel, San Francisco Aug. 9

Western Electronic Show and Convention (WESCON), Fairmount Hotel and Cow Palace, San Francisco Aug. 20-23

American Institute of Electrical Engineers, Pacific General Meeting, Pasco High School, Pasco, Washington Aug. 26-30

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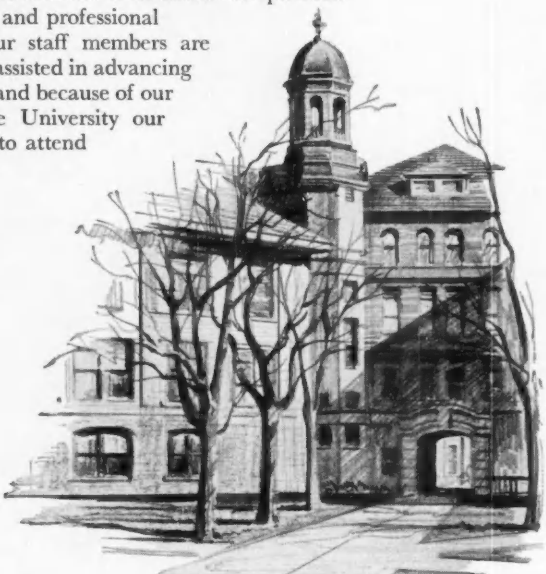

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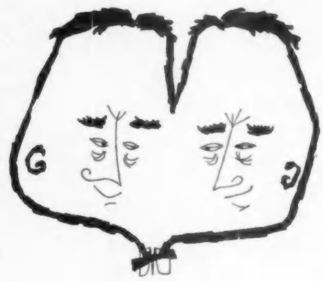

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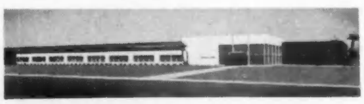

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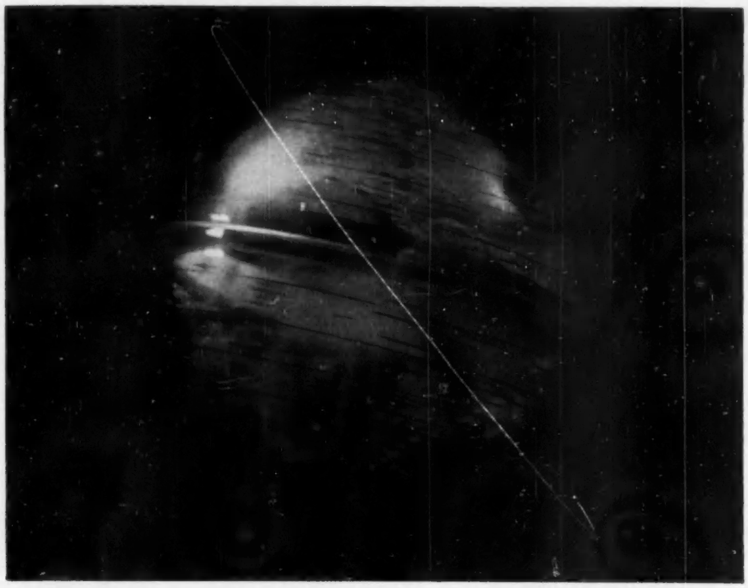

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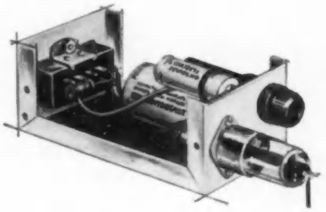

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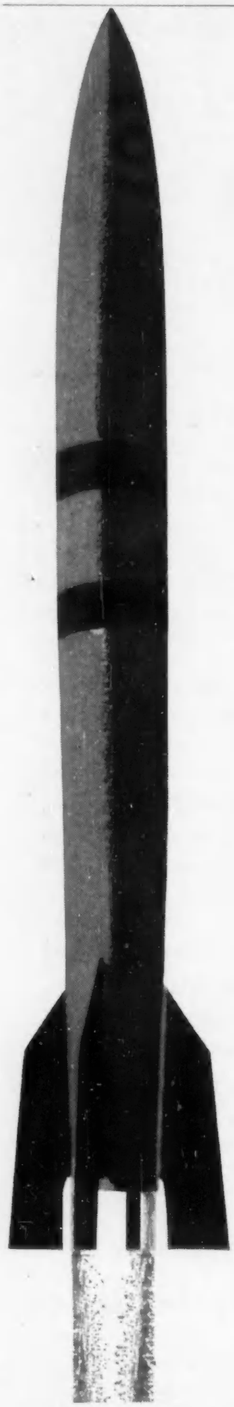

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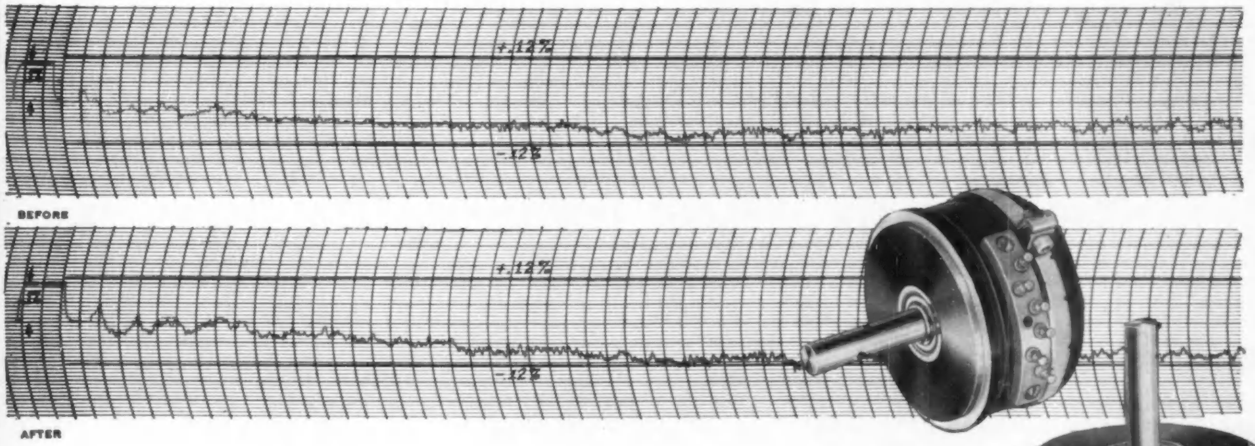

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